LANDSAT Data Continuity Mission

LDCM

LANDSAT DATA CONTINUITY MISSION (LDCM)

OPERATIONS CONCEPT DOCUMENT

Revision - Draft

December 5, 2006

NOT A REQUIREMENTS DOCUMENT

USGS
science for a changing world

Signature Page

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Document Revision History

This document is controlled by the LDCM Project Management. Changes require prior approval of the LDCM Project Management. Proposed changes shall be submitted to LDCM Mission Systems Engineer.

RELEASE	DATE	BY	DESCRIPTION
Draft	December 5, 2006		Draft version; reference document for OLI Draft RFP

List of TBD's/TBC's/TBR's

This document contains information that is complete as possible. Items that are not yet defined are annotated with TBD (To Be Determined). Where final numerical values or data are not available, best estimates are given and annotated TBC (To Be Confirmed). If there is an inconsistency between two requirements then the best estimate is given and annotated with a TBR (To Be Resolved). The following table summarizes the TBD/TBC/TBR items in the document and supplements the revision history.

ITEM	REFERENCE	DESCRIPTION
TBD	3.2.2	Location of Mission Operations Center
TBD	3.2.2.8	Location of backup Mission Operations Center
TBD	3.2.3	Location of backup LDCM ground station

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1 Introduction

The Landsat Data Continuity Mission (LDCM) is a joint mission being formulated, implemented, and operated by the National Aeronautics and Space Administration (NASA) and the Department of Interior (DOI) United States Geological Survey (USGS). The LDCM is a remote sensing satellite mission providing coverage of the Earth's land surfaces. This mission continues the 33+ years of global data collection and distribution provided by the Landsat series of satellites.

1.1 Purpose

The primary purpose of the LDCM Operations Concept (OpsCon) document is to provide a description of the planned functions and operations of the LDCM System comprised of space and ground assets. The OpsCon is not a requirements document and does not contain LDCM requirements. Rather, the OpsCon presents a functional view of the LDCM system and operations based on high level program guidance. It represents the operational approaches used to develop and set context for mission and segment requirements. Functions and scenarios described in this OpsCon are not intended to imply design or implementation approaches for the specific elements comprising the LDCM System.

1.2 Scope

The scope of the OpsCon includes all functions associated with the LDCM System as well as those external entities that interact with the LDCM System. Thus, the OpsCon encompasses the collection of image data by the observatory, transmission of data to the ground, and processing, archival, and distribution of the data for the Landsat data user community.

1.3 Background

The Landsat Data Continuity Mission is a component of the Landsat Program conducted jointly by the National Aeronautics and Space Administration and the United States Geological Survey (USGS) of the Department of Interior. The goal of the LDCM is to continue the collection, archival, and distribution of multi-spectral imagery affording global, synoptic, and repetitive coverage of the Earth's land surfaces at a scale where natural and human-induced changes can be detected, differentiated, characterized, and monitored over time. The LDCM goal is in keeping with the Landsat programmatic goals stated in the United States Code (USC) Title 15, Chapter 82 "Land Remote Sensing Policy" (derived from the Land Remote Sensing Policy Act of 1992). This policy requires that the Landsat Program provide data into the future that is sufficiently consistent with previous Landsat data to allow the detection and quantitative characterization of changes in or on the land surface of the globe. The LDCM was conceived as a follow-on mission to the highly successful Landsat series of missions that have provided satellite coverage of the Earth's continental surfaces since 1972.

The data from these missions constitute the longest continuous record of the Earth's surface as seen from space.

The LDCM is intended to ensure that Landsat-like data will be provided to the USGS National Satellite Land Remote Sensing Data Archive (NSLRSDA) for at least 5 years.

1.4 LDCM Mission Objectives

The major mission objectives are as follows:

- Collect and archive medium resolution (*circa* 30 m spatial resolution) multi-spectral image data affording seasonal coverage of the global land mass for a period of no less than five years.
- Ensure that LDCM data are sufficiently consistent with data from the earlier Landsat missions, in terms of acquisition geometry, calibration, coverage characteristics, spectral characteristics, output product quality, and data availability to permit studies of land cover and land use change over multi-decadal periods.
- Distribute LDCM data products to the general public on a nondiscriminatory basis and at a price no greater than the incremental cost of fulfilling a user request.

1.5 Roles and Responsibilities

NASA and USGS, as Landsat Program Management, will share the overall responsibility of fulfilling the LDCM mission objectives and all subsequent requirements. The roles and responsibilities related to this OpsCon are as follows:

NASA will

- Acquire and manage the development of the LDCM Space Segment and Mission Operations Element of the Flight Operations Segment
- Acquire and manage the LDCM Launch Services Segment;
- Serve as LDCM mission integrator
- Manage the LDCM observatory (integrated spacecraft and imaging sensor(s)) on-orbit operations from launch through on-orbit acceptance; and
- Transition LDCM mission operations capabilities and observatory operational and maintenance responsibility to USGS, following on-orbit acceptance.

USGS will:

- Manage the development and operation of the LDCM Data Processing, and Archive Segment;
- Manage the development, integration and operation of the LDCM Flight Operations Segment
    - Manage the development and operations of the LDCM Ground Network;
    - Manage the development and operations of the LDCM imaging sensor(s) Collection Activity Planning Element
    - Manage the operations of the Mission Operations Element following observatory on-orbit acceptance

- Operate the LDCM observatory following on-orbit acceptance; and throughout the life of the mission.

1.6 Document Organization

Section 1 of the document provides the introduction to the LDCM and this Operational Concept Document. Section 2 provides a high level overview of the LDCM System. Section 3 describes the LDCM operational concept as a series of segments and functions, sufficient to understand the system capabilities and interfaces. Section 4 presents an overview of the logistics support and sustaining engineering that will be provided to the LDCM. Section 5 describes the operational phases of the mission and illustrates LDCM operational scenarios for selected sequences of events during the mission life. Section 6 presents a design reference case, capturing several relevant operational activities conducted during a series of LDCM orbits.

1.7 Reference Documents

Document Number	Revision/ Release Date	Document Title
427-02-06	Dec. 4, 2006	LDCM Acronym List and Lexicon
427-05-01	Dec. 4	Operational Land Imager (OLI) Statement of Work
427-05-03	Dec. 4	OLI Requirements Document
427-09-XX	Draft	LDCM Mission Operations Element Requirements Document
427-05-04	Dec. 4, 2006	OLI Special Calibration Test Requirements (SCTR)
427-02-07	Dec. 4, 2006	LDCM World Reference System -2
NPR 2810.1A	May 16, 2006	NASA Procedural Requirement, Security of Information Technology
NPD 8710.3B	April 28, 2004	NASA Policy for Limiting Orbital Debris Generation
NSS 1740.14	August 1995	NASA Safety Standard, Guidelines and Assessment Procedures for Limiting Orbital Debris
NPR 1600.1	November 3, 2006	NASA Security Program Procedural Requirements

2 System Concept

The LDCM System includes all components and capabilities, both space and ground based, that are under the developmental and operational responsibility of the LDCM NASA-USGS interagency team. For mission definition and formulation purposes, the LDCM System is defined at the highest level in terms of four segments - the Space Segment, Flight Operations Segment, Data Processing and Archive Segment, and the

Launch Segment. See Figure 2-1. It should be noted that the specific functions within these segments may change during the implementation phase of the LDCM.

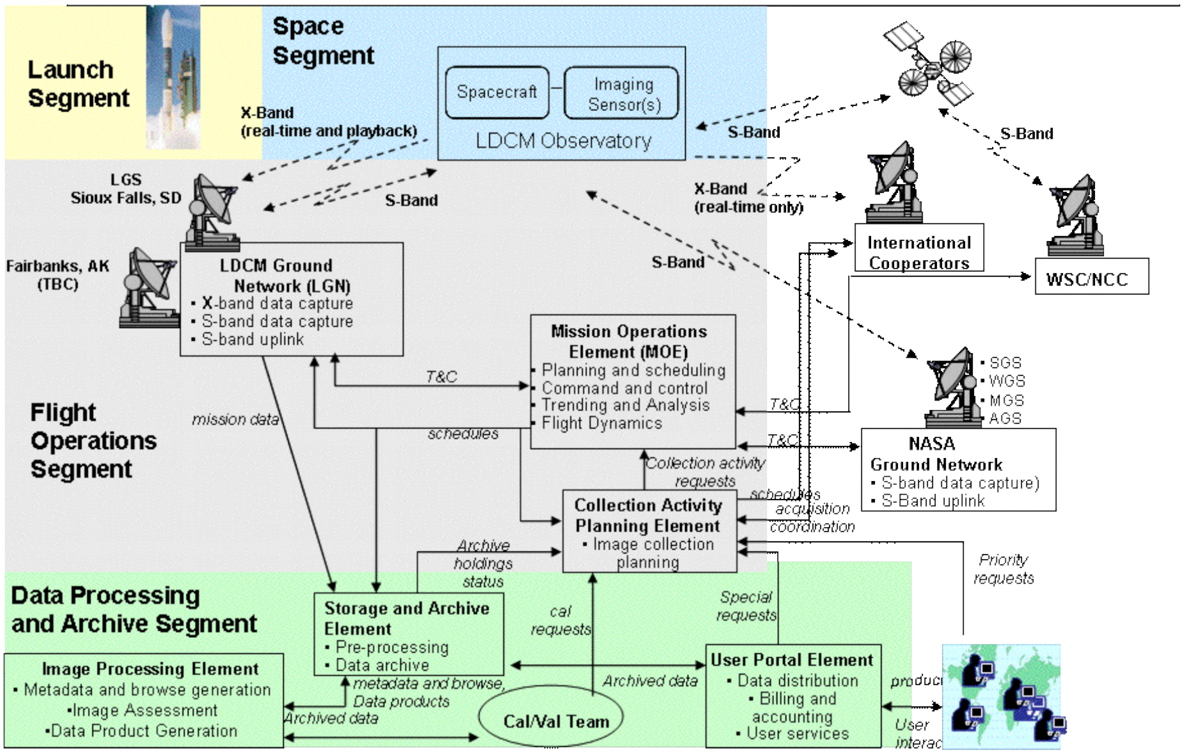

Figure 2-1: LDCM System and Operations Concept

2.1 Space Segment

The Space Segment (SS) consists of the observatory and pre-launch ground support equipment (GSE). The observatory is comprised of the imaging sensor(s) and the spacecraft platform. The observatory will operate in a 716 Km orbit with a 16-day repeat cycle and a 10:00 a.m. (+/- 15 minutes) mean local time for the descending node. Imaging sensor and ancillary data (combined as mission data) will be collected, stored onboard and subsequently downlinked to ground stations within the LDCM Ground Network via an X-band communications link. This link will also include stored housekeeping telemetry. Additionally, a real-time X-band downlink capability will transmit mission (imaging sensor and ancillary) data to the LDCM Ground Network and International Cooperators (ICs) equipped to receive these data. The observatory will also receive and execute commands and transmit real-time housekeeping telemetry via and S-band link to the LDCM Ground Network. The GSE provides the functionality to perform ground-based integration and testing of the observatory prior to launch.

2.2 Flight Operations Segment

The Flight Operations Segment (FOS) includes Collection Activity Planning Element, the Mission Operations Element, and the LDCM Ground Network Element. The Collection Activity Planning Element (CAPE) develops a set of image collection and imaging sensor(s) calibration activities to be performed by the observatory. The Mission Operations Element (MOE) converts the CAPE input to specific imaging sensor and observatory activities; plans, deconflicts, and schedules these activities; commands and controls the observatory; and monitors the health and status of the observatory and ground operating systems. The MOE hardware and software systems reside in the LDCM Mission Operations Center (MOC). There is also a backup MOE (bMOE) which resides in a geographically separated backup MOC (bMOC). The LDCM Ground Network (LGN) includes the ground stations that will communicate with the observatory for commanding and monitoring, and will receive mission data from the observatory. The LGN will route mission data and observatory housekeeping telemetry to the Data Processing and Archive Segment.

2.3 Data Processing and Archive Segment

The Data Processing and Archive Segment (DPAS) ingests, processes, and archives all LDCM mission data. Storage and Archive Element perform ingest and long-term archiving. The Image Processing Element processes all data to create LDCM data products, and performs image assessment. This includes the generation of WRS-2 scenes, including scene overlap regions. The LDCM Independent Cal/Val team interacts with the image assessment capability to assess data quality and update calibration parameters. A capability to receive and fulfill user requests for LDCM image collections and data products is provided by the DPAS User Portal Element. The DPAS will be located at the USGS Center for Earth Resources Observation and Science (EROS) in Sioux Falls, SD.

2.4 Launch Services Segment

The Launch Segment (LSS) provides those assets and services associated with the launch vehicle (LV) and the observatory to launch vehicle integration. Included, along with the launch vehicle, are all launch vehicle ground support equipment (including hardware and software), property, and facilities to integrate the observatory to the LV, verify their integration, and conduct pre-launch testing with ground-based functions.

2.5 LDCM System Interfaces

There are certain external entities that provide information to, or receive information from the LDCM System.

<u>NASA Space Network</u>
NASA's Space Network (SN) will provide S-band communications capabilities for LDCM. The SN Tracking and Data Relay Satellite System (TDRSS) will provide bi-directional data transmission services between LDCM and ground receiving stations, using satellite to satellite communications links to allow communications even when LDCM is not in view of a ground station. LDCM will utilize the SN during launch and early orbit for S-band uplink and downlink operations. Following commissioning, the SN will only be used to support observatory emergency operations.

NASA Ground Network

The NASA Ground Network (NGN) includes several satellite ground receiving stations throughout the world that are available to support NASA missions. LDCM will interface with a subset of NGN stations for support during launch and early orbit operations. Following commissioning, the NGN will only be used in support of observatory emergencies. The NGN stations will provide S-band services for uplink and downlink only, no X-band reception.

External Data Sources

LDCM will utilize certain external data as input to the Flight Operations Segment and the Data Processing and Archive Segment. These data will include auxiliary data such as government-provided ground control data and digital elevation models for terrain correction or lunar radiance data to support imaging sensor calibration. External data will also include cloud prediction information used in data collection scheduling, or other data that are used to operate the mission or produce LDCM data products.

U.S. Strategic Command (USSTRATCOM)

The U.S. Strategic Command (USSTRATCOM) presently supports NASA'S Space Network and Earth science missions by performing routine conjunction assessment. This facility sends a message to the LDCM FOS whenever there is a possible conjunction with a safety buffer around LDCM. The conjunction analysis is based upon LDCM state vector information, provided to the Constellation Coordination System (refer to description below). There are three levels of warning, with three associated volumes used for the conjunction analysis.

Constellation Coordination System

The Constellation Coordination System is an existing utility that provides easy exchange of orbit data between missions. The LDCM FOT will upload observatory state vectors to the CCS to support conjunction analyses performed at USSTRATCOM.

Earth Science Mission Operations (ESMO)

The ESMO office at NASA GSFC is responsible for the operation of several NASA Earth science missions. The LDCM orbit will allow LDCM to fly as part of a morning constellation that includes several ESMO missions, if they are still operational. (This constellation presently consists of Landsat 7, Terra, SAC-C, and EO-1.) Any required orbit or maneuver coordination to maintain this constellation is performed through human interaction with the ESMO staff and the potential exchange of state vectors corresponding to observatory orbits.

NASA Flight Dynamics Facility

The NASA Goddard Space Flight Center maintains a Flight Dynamics Facility that provides attitude and orbit determination, prediction, and control services. The LDCM will utilize FDF services during early orbit and for anomaly resolution activities.

2.6 Primary Internal & External Users

This section describes the groups and teams that use or interact with the capabilities of the LDCM.

User Community

The User Community encompasses all those members of the general public that use Landsat data for purposes as diverse as scientific research and operational resource management. The User Community interfaces to the Data Processing and Archive Segment to search for, browse, order, and receive LDCM data products, and to request image collections

International Cooperators

The USGS maintains agreements with several foreign entities (typically, governmental) referred to as the LDCM International Cooperators (ICs). The ICs are a special subset of the User Community that has the ability to receive LDCM data from the observatory real-time downlink stream. Real-time imaging sensor and ancillary data (including spacecraft, calibration data, etc.) necessary for processing are contained in the real-time stream and are received by IC ground stations. The number of active IC ground stations is not constant. IC ground stations may move to/from an active condition based upon the state/terms of their respective Landsat agreement, funding conditions, or the technical capabilities of the IC ground station. A list of current Landsat 5 and Landsat 7 ICs is included in Appendix A for reference purposes.

Flight Operations Team (FOT)

The LDCM Flight Operations Team (FOT) is the team of mission operations personnel managed by the USGS. The LDCM FOT will use the Flight Operations Segment to operate the observatory from launch vehicle separation through the life of the mission.

Data Collection Planner

The USGS Data Collection Planner (DCP) manages the data collection schedules for LDCM. The DCP operates the Collection Activity Planning Element within the Flight Operations Segment. The DCP may be an individual or a team of staff who share the DCP responsibilities.

Landsat Science Team

The USGS convenes a Landsat Science Team composed of competitively selected investigators. The Team will conduct research on issues critical to the success of the LDCM, including data collection, product access and format, practical applications, and science opportunities for new- and past-generation Landsat data. The Team will offer research and science support to the USGS on topics that will affect the overall success of the LDCM mission. The USGS and NASA LDCM Project Scientists will co-chair the Science Team.

Independent Cal/Val Team

The Independent Calibration/Validation (Cal/Val) team consists of discipline scientists and engineers who perform calibration of the LDCM imaging sensor(s) and data. The

Independent Cal/Val Team is geographically dispersed and includes members from both NASA and USGS. While the team will advise on and review imaging sensor calibration activities, they will remain independent from the development contractor/organization in their calibration assessments through the life of the mission. NASA leads this team during observatory development through on-orbit acceptance. Following on-orbit acceptance, this team is led by USGS. The Independent Cal/Val Team works with members of the LDCM Science Team on various calibration and validation issues and special collections of LDCM data.

3 Functional View of Operational Concept

The LDCM operational concept is presented in this section as a set of functions required to operate the LDCM. The allocation of functions to specific segments and any grouping of functions within segments are based on experience gained from developing similar systems. However, this allocation is not meant to constrain the LDCM system architecture that will be defined later in the development cycle. Therefore, while the objective of the OpsCon is to capture all necessary functionality of the LDCM operations, some functions may ultimately be allocated to different segments at a later time.

3.1 Space Segment

The LDCM observatory and associated GSE make up the Space Segment. The LDCM observatory consists of the spacecraft and imaging sensor(s).

3.1.1 Observatory

Planned for a 5 year minimum mission life, the LDCM observatory will operate in 716 Km sun-synchronous orbit. The observatory will have a 16-day ground track repeat cycle and a 10:00 a.m. (+/- 15 minutes) mean local time of the descending node. This will allow imaging sensor data to be referenced to the second Worldwide Reference System (WRS-2) as part of the ground processing performed by the Data Processing and Archive Segment (Section 3.3).

The LDCM observatory will perform the standard functions of image data collection, communications, command and data handling, and attitude and orbit control. The observatory will receive S-band communications from LDCM ground stations nominally, and from the SN and NGN during launch and early orbit or contingency/emergency operations. Commands and spacecraft software updates received via the S-band communications stream will be managed on-board, and forwarded to the respective observatory sub-systems for execution. The observatory will nominally receive command loads every 24 hours, and each will encompass 72 hours of observatory activity. If an updated command load has not been received at the end of the 72 hour period, the observatory will automatically enter a safe operational state. The observatory will monitor the health and status of each sub-system including the imaging sensor(s). Corresponding housekeeping telemetry will be generated and stored on-board for future transmission. During contacts with a ground network station, the stored and real time housekeeping telemetry data will be downlinked. Stored observatory housekeeping telemetry data may also be downlinked over the X-band link.

The observatory will have the ability to generate on-board ephemeris and manage spacecraft timing. Navigation and attitude sensor data (raw and processed) will be stored and transmitted as part of the observatory telemetry. The observatory will be capable of attitude and orbit adjustments, as commanded by the Flight Operations Segment, to maintain the WRS-2 ground track and related image quality requirements, and to perform required calibration maneuvers. Power and thermal management functions will also be performed on-board.

If any of a pre-defined list of anomalies occurs, the observatory will have the ability to detect the anomaly. If the severity of the anomaly warrants it, the observatory will automatically place itself in a safe and protected state until the anomaly is resolved.

The LDCM observatory imaging sensor(s) will nominally collect multispectral image data of the Earth nadir to the WRS-2 ground track. Additionally, the observatory will be able to collect off-nadir image data up to 15 degrees on either side of the observatory ground track, in lieu of imaging the nadir WRS-2 path. The observatory will collect images of the moon for imaging sensor calibration. Due to changes in the moon phase, the observatory will perform lunar calibrations during one of the two approximately 8-hour long windows that occur every lunar cycle (approximately 28 days). The observatory may also perform additional instrument or attitude sensor calibrations using on-board calibration systems or other maneuvers (e.g. gyro calibration maneuver), if necessary.

The observatory will nominally collect image data equivalent to produce 400 individual scenes per 24-hour period plus any required routine calibration and housekeeping telemetry data needed for processing the 400 scenes. (It is noted that non-routine events, such as lunar calibrations, may impact the amount of image data collected in a given day.) All image data collections and corresponding image intervals are selected and scheduled by the Flight Operations Segment as described in the next section. Image collections will include data to support global change research, International Cooperators, special requests, and all daytime scenes over the United States.

Nominally, all imaging sensor data will be temporarily stored on board the observatory. When commanded by the Flight Operations Segment, image data will be transmitted to the ground via an X-band communications stream. X-band transmissions will be performed using either an omni or direct beam antenna architecture. The X-band data stream will contain the image data and ancillary data, including imaging sensor and select spacecraft housekeeping telemetry, calibration data, and other data necessary for image processing.

The observatory will transmit X-band data in both playback and real-time modes to the LDCM ground stations. The observatory will also transmit real-time X-band data to ICs. Nominally, all real-time data will be stored on board for subsequent downlink to an LDCM ground station. However, the observatory will also be capable of downlinking X-band data in real-time, without storing it on board. The observatory will be capable of transmitting to the LDCM ground stations (in real-time and dual playback streams) the equivalent of at least 400 scenes and associated calibration data per 24-hour period. The observatory will be capable of re-transmitting telemetry and image data if the original transmission was not properly received.

When communicating with the LDCM ground stations, the observatory will be capable of performing the following functions concurrently during a nominal day time contact:

- Receipt of S-band communications
- Transmission of real-time housekeeping telemetry
- Storage of real-time housekeeping telemetry
- Transmission (playback) of stored housekeeping telemetry

AND

- Transmission of real-time mission data
- Storage of real-time mission data
- Transmission of one unique (playback) stored mission data stream

OR

- Storage of real-time mission data
- Transmission of up to two unique (playback) stored mission data streams

When communicating with the LDCM ground stations, the observatory will be capable of performing the following functions concurrently during a nominal night time contact:

- Receipt of S-band communications
- Transmission of real-time housekeeping telemetry
- Storage of real-time housekeeping telemetry
- Transmission (playback) of stored housekeeping telemetry
- Transmission of up to two unique (playback) stored mission data streams

It should be noted that if any night time imaging sensor data is being collected during an LGN contact, mission data could be transmitted to the LGN ground station via one real-time stream and one unique playback stream during a night time contact.

When communicating with the IC ground stations, the observatory will be capable of performing the following functions concurrently:

- Storage of real time housekeeping telemetry
- Transmission of real-time mission data
- Storage of real-time mission data

When in view of both an IC ground station and an LGN station concurrently, the observatory will be capable of performing the following mission data downlink functions concurrently:

- Transmission of real-time mission data to an IC station
- Storage of real-time mission data

AND

- Transmission of real-time mission data to the LGN station
- Transmission of one unique (playback) stored mission data stream to the LGN station

OR

- Transmission of up to two unique (playback) stored mission data streams to the LGN station

Storage and downlink of imaging sensor data on the observatory will be managed from the ground Flight Operations Segment. The Flight Operations Segment will schedule imaging sensor data for downlink. Nominally, oldest data will be downlinked first. However the observatory, as commanded by the Flight Operations Segment, will downlink priority image data collections (see section 3.2.1) in advance of non-priority collections to the first available LDCM ground station. If a priority image collection is in an IC region, the priority collection will be real-time downlinked to that IC and stored on-board for priority downlink to the first available LDCM ground station.

The observatory will be capable of protecting selected mission data in observatory mass storage from being overwritten by future image collections. The protect capability will be applied and commanded by the Flight Operations Segment to selected image collections or to all image data collected. Nominally, all data will be protected until it has been successfully downlinked to the ground. Immediately after downlink is confirmed, likely during the same ground station contact, the successfully downlinked data will be made available for overwriting via ground commands. (See Section 3.2.2.5.) If downlink cannot be confirmed, data may remain protected on-board until the next available LDCM ground station contact. The observatory will overwrite data in the following precedence: in free or empty storage locations, then into unprotected locations. For storage locations that contain unprotected data, the data will be overwritten oldest first. If mass storage capacity is reached with all data protected, the observatory will automatically stop storing any additional data in mass storage.

3.1.2 Observatory Simulator

A key component of the space segment, although resident on the ground, is the observatory simulator. The observatory simulator simulates the interaction between the LDCM Mission Operations Element and the actual LDCM flight observatory with high fidelity. The observatory simulator will reside in the LDCM Mission Operations Center. See section 3.2.2 for additional explanation.

3.1.3 Ground Support Equipment

Both electrical and mechanical Ground Support Equipment (GSE) interfaces to the LDCM observatory are essential to successful observatory integration and verification. The electrical GSE originates test commands and receives responses from the observatory during observatory level integration and test. The mechanical GSE is used during final assembly of the observatory for the installation and testing of any mechanical components.

A subset of the integration and test GSE will travel to the launch site to support observatory final preparations for launch. The electrical GSE at the launch site will be used in the payload process for launch as well as during the launch count down to place LDCM observatory in its final launch configuration.

3.2 Flight Operations Segment

The LDCM Flight Operations Segment (FOS) includes all of the ground-based assets needed to operate the LDCM observatory. The primary components of the FOS are the Collection Activity Planning Element; Mission Operations Element; and the LDCM Ground Network.

The overall activity planning for the mission is split between the Collection Activity Planning Element (CAPE) and the Mission Operations Element (MOE). The CAPE schedules activities on a path-row scene basis. The MOE converts CAPE-generated path-row scenes to observatory activities, schedules these and any other detailed observatory activities, and generates commands necessary to collect the identified scenes and operate the observatory. The MOE schedules activities such as orbit maneuvers and identifies these to the CAPE as periods where science data collection cannot occur.

3.2.1 Collection Activity Planning Element

The FOS Collection Activity Planning Element functions build and manage collection activity requests for the LDCM imaging sensor(s). The collection activity requests include:

- Imaging requests to support the LDCM Global Mission Acquisition Plan (GMAP), which provides requirements for Earth land imagery collections based on seasonality, cloud climatology, and other factors.
- International Cooperator imaging requests
- All daytime imaging sensor data over the United States, regardless of cloud cover
- Calibration-related Earth imaging requests
- Special imaging requests

Daily cloud cover predictions from the National Center for Environmental Prediction (NCEP) are input to the CAPE to identify the best opportunities to collect cloud-free images. Factoring in cloud cover and any observatory resource constraints provided by the MOE, the CAPE processes all the requests and performs any de-confliction to develop the collection activity request. This request is a scene-based list of images to be collected by the imaging sensor(s). The CAPE will assign each scene or imaging sensor(s) activity in the request a unique identifier. (e.g. path, row, and date) The unique identifies will be shared with the Mission Operations Element and the Data Processing and Archive segment so that every individual scene requested can be tracked throughout the entire planning, collection, and production process.

The collection activity request is optimized to meet a maximum number of requests while fulfilling the GMAP requirements. The criteria for prioritizing collection requests will be defined and documented within CAPE operating procedures. The CAPE will nominally generate a collection activity request every 24 hours, and each request will encompass up to 72 hours of activities. Collection activity requests may be generated more frequently in response to time-critical special requests (priority requests) or other special circumstances.

Special imaging requests, such as for natural disasters or to support unique science research campaigns, are forwarded to the LDCM Data Collection Planner (DCP) – a USGS team member(s) responsible for coordinating and approving special requests. The DCP interacts with the CAPE functions of the FOS. The Data Collection Planner evaluates the special requests using the prioritization criteria and determines whether or not they will be scheduled for collection. Certain special requests, called priority requests, are those time-critical image collections of national or international interest (e.g. natural disasters). Priority requests are flagged by the DCP to be expedited through the entire image collection and production process.

The DCP may flag selected image collection requests for protection. The DCP may request protected data to be re-downlinked if it has not been successfully received. The DCP may also remove the protect flag in certain cases where the DPAS confirms successful data receipt following cursory image quality checks. The flagging (or unflagging) of priority and protected data is included within the collection activity request provided by the CAPE to the MOE.

3.2.2 Mission Operations Element

The FOS Mission Operations Element includes four primary functions; Planning and Scheduling; Command and Control; Flight Dynamics; and Trending and Analysis. Additional mission operations functions of flight software and mass storage management are also performed by the MOE. The capabilities to perform these functions will physically reside in the Mission Operations Center (MOC), a government-provided facility located at TBD. The MOE and MOC will support a variety of staffing levels as determined by life cycle operations systems maturity.

A limited number of MOE functions will be available through remote access. Remote access to selected MOE functions such as trending data and observatory subsystem real-time telemetry will allow FOT members or observatory engineering support staff to support operations without being present in the MOC. Observatory commanding will *not* be performed via remote access.

3.2.2.1 Planning and Scheduling

Planning and Scheduling (P&S) functions will plan/coordinate and schedule observatory and ground station activities. Key inputs to this function are the collection activity requests developed by the CAPE. Upon receipt of the collection activity request, the MOE will convert/assign requested scenes to imaging intervals – periods of time when imaging sensor data is collected. Imaging intervals will be assigned a unique identifier and the MOE will maintain a scene/activity to interval mapping table. The imaging interval identifier will be referenced in MOE commands for downlink and management of data (files) in observatory mass storage. Any collections marked as priority will be managed and tracked within the MOE for expedited downlink. Any collections marked as protected will be identified within the observatory commands so as to be protected from overwriting in observatory mass storage. The MOE will be able to remove priority and protected flags based on input from the CAPE.

In addition to the CAPE collection activity requests, P&S will plan and schedule

- Observatory activities such as orbit adjustments, maneuvers, and housekeeping data downlinks
- Lunar, solar, and other non-Earth imaging calibration activities
- Downlink of imaging sensor(s) data, including the downlink of priority data in advance of non-priority to the first available LDCM ground station and re-downlink of data
- Ground station contacts including those to the LDCM Ground Network, ICs, and those performed through the SN and NGN.
- Ground network activities required to transfer data between ground stations and the MOE or DPAS.
- Upload of operational data tables, flight software updates, etc.

In order to develop activity plans and schedules, the MOE will also perform activity management functions such as activity prioritization, activity resource allocation, and allocation of operational constraints. (The MOE will not prioritize image collection activities since this will be done by the CAPE.) Mission health and safety activities will be given higher priority over image collections.

Imaging sensor calibration activities that impact opportunities for nominal Earth imaging, such as lunar calibrations, will be coordinated between the Cal/Val Team and Flight Operations Team in the MOC. Calibration activities will typically be given priority over nominal Earth imaging. Such calibration events will be included in observatory activity plans that are provided to the CAPE so that Earth imaging is not planned during these periods.

Other MOE resource management activities include keeping track of ground systems hardware and software downtimes and preventive maintenance.

Incorporating the collection activity requests, the P&S functions will plan and schedule observatory activities, perform constraint checking and schedule de-confliction, and generate the observatory activity schedule. Planning and Scheduling will nominally generate an activity schedule every 24 hours, and each schedule will encompass 72 hours of observatory operations. Activity schedules may be generated more frequently in response to priority requests or other special circumstances. Activity schedules will be provided to the CAPE, DPAS, and LDCM ground stations for feedback/planning purposes.

3.2.2.2 Command and Control

The MOE Command and Control functions build command loads for transmission to the observatory. Command loads are built to implement observatory activity schedules and flight software updates. Observatory activity schedules will be received from the P&S function. Nominal daily command loads will be automatically rule- and constraint-checked prior to uplinking. Commands will be encrypted and routed to the LDCM Ground Network or through the SN or NGN (during early orbit and contingencies) for transmission to the observatory. Commands will only be generated from a single MOC terminal at any given time. That is, only one FOT member resident in the MOC will have the ability to command the observatory at any given time.

The Command and Control functions will monitor the LDCM observatory beginning with the receipt of real-time (RT) and stored housekeeping telemetry from the LDCM Ground Network or through the SN or NGN (for early orbit and contingencies). Housekeeping telemetry will be monitored and limit checked. Out of limit values will trigger visual indicators, alarms, or other notification (e.g. paging) of the Flight Operations Team (FOT).

3.2.2.3 Flight Dynamics

The MOE Flight Dynamics functions include

- Orbit analysis and propagation
- Maneuver planning in order to support orbit maintenance, off-nadir imaging, calibration, and decommissioning maneuvers
- Calibration of any observatory on-board attitude sensors or propulsion components
- Generation of predicted ground station and SN contact/view periods
- Processing of on-board ephemeris data to produce predicted ephemeris that support planning and scheduling events
- Processing of on-board attitude sensors data to produce attitude history data

3.2.2.4 Trending and Analysis

All housekeeping telemetry for the mission will be stored on or near line by the MOE to support Trending and Analysis functions. A suite of analysis tools within the MOE will be used by the FOT and engineers to perform long-term trending, analysis, anomaly investigation, etc. With these functions, FOT personnel can generate automated and user-definable statistics, plots, and reports. The MOE will also send processed housekeeping telemetry data to the DPAS for use in image processing and image assessment.

3.2.2.5 Flight Software Management

Modifications or updates to observatory flight software will be performed by the development contractors/organizations for the spacecraft and imaging sensor(s). Flight software modifications/updates will be provided to the MOE for upload to the observatory. All flight software update command loads will be tested first on the observatory simulator prior to upload to the flight observatory. The MOE will maintain version control of the observatory flight software.

3.2.2.6 On-board Mass Storage Management

The MOE will manage the observatory mass storage by monitoring mass storage utilization, scheduling data in mass storage for downlink and by monitoring the downlink of imaging sensor data through data receipt status messages received from the LGN ground stations. Imaging sensor data that has been successfully received by the LGN station will be commanded by the MOE to be unprotected and available for overwriting in observatory mass storage. Successful receipt will be indicated in the status messages received by the MOE from the LGN ground stations. It is anticipated that commanding for un-protection will occur near the end of the same LGN contact in which the data was received. On a non-routine basis, certain successfully received data may be retained on board until the DPAS confirms successful receipt. This could occur for very special, high priority image collections, and would be managed by the MOE and coordinated through the CAPE and DPAS.

3.2.2.7 MOE Interface to Simulator

The LDCM Observatory Simulator will be integrated within the LDCM MOC and will interface directly to the MOE. The LDCM Observatory Simulator will be used by the FOT to simulate interactions between the MOE and the flight LDCM Observatory. It will be a high fidelity observatory simulator that receives and executes commands, and generates simulated telemetry for analysis by FOT personnel. It simulates the capabilities of the observatory and its subsystems, including the LDCM imaging sensor(s).

The observatory simulator will be used, at a minimum, for the following:

- FOT training
- Procedure validation
- Maneuver rehearsals and validation
- Flight software updates testing and validation
- Anomaly investigation and resolution

3.2.2.8 Autonomy

The MOE will have the capability to support unattended operations for up to a 72 hours contiguous period. Unattended operations include autonomous contacts with ground stations, downlink of housekeeping and mission data, real-time monitoring of the housekeeping telemetry data, monitoring of imaging sensor data receipt acknowledgements, and commanding to unprotect received mission data. The MOE system will be capable of autonomously monitoring and reporting MOE systems status.

Any mission-critical anomalies detected in housekeeping telemetry or within the MOE system will cause the MOE to autonomously activate a notification and call-in system for the FOT. Autonomous mission operations capabilities will not be used early in the mission, during maneuvers, or other times of increased risk.

3.2.2.9 Backup MOE and Backup MOC

The FOS will include a backup MOE (bMOE). The bMOE will have all the capabilities of the MOE, and will interface to the observatory simulator in the primary MOC via network connection. The bMOE will be located in a backup MOC facility at a location geographically separated from the primary MOC, so that it can serve as a backup in the event of a critical failure, malicious attack, or natural disaster at the primary MOC facility. The location of the bMOC is TBD. The primary MOE will routinely share/update command and control data and information with the bMOE so that the bMOE can assume operations of the LDCM with no risk to mission health and safety, and minimal impact to image data collection.

3.2.3 LDCM Ground Network Element

The FOS includes a ground-based capability for communicating with the observatory, called the LDCM Ground Network. The LDCM Ground Network is comprised of two nodes located at Sioux Falls, SD and Fairbanks, Alaska. These stations will be fully dedicated to LDCM. A third station at TBD location will be used as a backup.

Each node in the LDCM Ground Network includes a ground station that will be capable of receiving LDCM X-band data. Additionally, each station provides complete S-band uplink and downlink capabilities. These enable the Mission Operations Element to interface to the observatory. During an X-band mission data downlink event, the LGN ground station will monitor the downlink and provide the MOE, in near real time, a status of mission data that was successfully received by the ground.

The LDCM Ground Network includes a data routing capability. This allows the transfer of X-band mission data to the DPAS and the transfer of commands/telemetry between the nodes and the MOE in a secure manner. Each LGN node will cache data received for a fixed period of time in case the data must be re-sent to the MOE or DPAS.

3.2.4 International Cooperators (ICs) Interface

The LDCM International Cooperators (ICs) will be capable of receiving real-time downlinks of X-band imaging sensor data. ICs will submit bulk requests for imaging sensor data collections in their respective regions to the CAPE, and the CAPE will provide feedback and downlink schedules to the ICs. Additionally, the ICs may submit individual scenes collection requests through the DPAS User Portal Element (Section 3.3.3).

3.2.5 NASA Space Network (SN) Interface

The LDCM will interface to the NASA Space Network (SN) Tracking Data Relay Satellite System (TDRSS). This interface will be used for S-band communications during the launch and early orbit of the LDCM observatory, and potentially for emergencies /

critical maneuvers / anomaly resolution. The LDCM Flight Operations Segment MOC and MOE will interface to the SN through the SN White Sands Complex (WSC) in Las Cruces, NM. The WSC will perform S-band communications directly with the SN satellites. Link service requests and real-time messaging will be transferred between the WSC and the MOE. The scheduling of SN capabilities will be performed through the SN scheduling tools resident in the MOC.

3.2.6 NASA Ground Network (NGN) Interface

The LDCM will interface to the NASA Ground Network (NGN). This interface will be used for S-band communications during the launch and early orbit of the LDCM observatory, and potentially for emergencies / critical maneuvers / anomaly resolution following commissioning. The LDCM will be compatible with the following NGN stations:

- Norway – SGS
- Wallops, Virginia 11.3m – WGS 11.3m
- McMurdo, Antarctica – MGS
- Poker Flat, Alaska – AGS

The LDCM Flight Operations Team will schedule NGN resources through the White Sands Complex (WSC) scheduling system called Wallops Orbital Tracking Information System (WOTIS). NGN stations will receive S-band communications form the observatory and route them to the MOE.

3.3 Data Processing and Archive Segment

The Data Processing and Archive Segment (DPAS) includes those functions related to ingesting, archiving, calibration, processing, and distribution of LDCM data and data products.

3.3.1 Storage and Archive Element

The Storage and Archive Element receives all LDCM mission data from the Flight Operations Segment LGN for archival. LDCM mission data are made available to the Image Processing Element and pre-processed into a format for archival (refer to section 3.3.2).

The Storage and Archive Element archives all LDCM data. The LDCM data includes LDCM raw and reconstructed mission data (imaging sensor(s) and ancillary data), auxiliary data, and mission related data (e.g. engineering and pre-launch test data, development and engineering documentation from all phases of the program). Auxiliary datasets include Digital Elevation Models (DEMs), water mask datasets, and ground control datasets. The total volume of the data archived is nominally 600 GB per day or 1 PB for a five year mission. A copy of all housekeeping data is also archived in the Storage and Archive Element for easy access by cal/val team members.

In addition, the Storage and Archive Element:

- Maintains the safety and integrity of all archive media, including the management of an offsite copy of all archived LDCM data.
- Maintains an archive database -- metadata information that describes all LDCM data in the archive.

3.3.2 Image Processing Element

The Image Processing Element includes all processing functions within the DPAS. This includes processing data for archival and generating data products.

The Image Processing Element generates browse imagery and metadata for all image collections stored in the LDCM archive. Additionally, all imaging sensor data is processed to ascertain quality assessment information. This processing includes verifying any checksum fields, performing limits checking on metadata parameters, etc. A quality assessment process also includes a visual inspection step performed by operations staff. Cloud cover scores, and other information are also generated.

The Image Processing Element extracts archived data granules for other requesting DPAS functions. The extraction activity may include extracting/combining data for a requested time interval, extracting only a certain set of bands, creating a seamless granule, etc. The Image Processing Element generates all the LDCM data products distributed by the DPAS, including standard Level 0 and Level 1 products. Standard product generation includes creating products in the form of WRS-2 scenes.

The Image Processing Element ensures that the LDCM data products meet all the radiometric, geometric and spatial performance requirements. This function uses stored data from the DPAS Storage and Archive Element to generate calibration parameters. The calibration parameters are used by the Image Processing Element to generate data products which meet performance requirements.

The Image Processing Element provides the capability to characterize LDCM products for radiometric, spatial and geometric performance. This refers to both Level 0 LDCM data and to all the Level 1 products generated by the Image Processing Element. This function also performs analysis of LDCM archive data (both sensor data and telemetry) to extract detector-level statistics and various calibration-related parameters and data.

The Image Processing Element has a critical human-in-the-loop element. The LDCM Independent Calibration and Validation (Cal/Val) Team oversees all calibration performed by this function. The Independent Cal/Val Team members, both NASA and USGS, perform analysis of calibration data and collectively decide on updates to LDCM calibration parameters and on the need for observatory calibration maneuvers and calibration data collections. The Independent Cal/Val Team serves in this role for the life of the mission.

3.3.3 User Portal Element

The User Portal Element provides the LDCM interface to data users, and manages the generation and completion of orders for LDCM data products. (Note that ICs may access the User Portal to order products as well.) The User Portal includes a discovery capability that allows users to search for LDCM data products, place orders, request LDCM image collections, and supports a bulk order capability. The bulk order capability supports a machine to machine interface to the User Portal.

The User Portal includes financial functions related to billing and accounting and the exchange of funds for data product sales and returns.

The User Portal provides public access to related LDCM information. This includes: Calibration reports; calibration data; documentation; data format descriptions and similar types of information.

3.4 Launch Services Segment

The Launch Services Segment consists of the Launch Vehicle (LV) and the associated facilities, equipment and services needed to place the LDCM observatory into orbit.

The LDCM will be launched from the Western Range at the Vandenberg Air Force Base (VAFB) located near Lompoc, California. The LDCM space segment will be transported to VAFB to prepare for launch. A payload processing facility (PPF) will be assigned at VAFB to support the final observatory integration and test activities required before launch.

3.4.1 Launch Vehicle

The LDCM launch vehicle and associated launch services will be procured by NASA's Kennedy Space Center (KSC). The LV will be a Delta II 7320-10C. The LV will be delivered to the launch site at VAFB. The LDCM observatory will be mated to the LV at the launch site.

3.4.2 Launch Vehicle Ground Support Equipment (LV-GSE)

The launch vehicle ground support equipment (LV-GSE) are those mechanical, electrical, communications, propulsion, and monitoring equipment needed to provide launch base services for the LDCM launch. The majority of the LV-GSE is unique to the LV and has few interfaces to the LDCM. There are several items in the LV-GSE that affect LDCM operations. These include:

- Blockhouse console for pre-launch power and commands to the observatory, and hard line monitors and telemetry from the observatory via the LV umbilical
- Communications interface equipment to allow command and telemetry from the observatory electrical GSE to interface with the observatory while it is mated to the LV
- Observatory handling equipment for mating the observatory to the LV, for installation of the fairing, and ensuring a temperature and humidity controlled environment

4 Logistics Support and Sustaining Engineering

The following logistical and sustaining engineering support will be provided as part of the LDCM operations.

4.1 Logistics Support

4.1.1 Facilities

The Facilities Logistics functions provide LDCM physical infrastructure. The physical infrastructure includes everything needed to operate the Flight Operations and Data Processing and Archive Segments except for the information technology infrastructure and the ground station antennas. A non-inclusive list of items provided as part of the physical infrastructure is:

- Power, including backup power
- Heat and air conditioning
- Environmental services
- Buildings, including operating buildings, warehouses, and storage areas
- Facility maintenance
- Roads
- Vehicles
- Construction
- Foundations for antenna

It is expected that most ground equipment will be located at a USGS facility, at a facility owned by another organization, or both. In either case, the LDCM will act as a tenant. Thus LDCM facilities logistics is primarily a management role – coordinating with the site facility manager for facilities needs and funding.

4.1.2 Protection

LDCM protection will address:

- Physical security of critical operations facilities such as the Mission Operations Center (MOC), backup MOC (bMOC), and ground station facilities as specified in the USGS LDCM System Protection Plan and NPR 1600.1.
- Information technology (IT) security to ensure secure operations of LDCM software or network capabilities as specified in NPR 2810.1A and the USGS LDCM System Protection Plan. IT security will also include the use of command uplink encryption and authentication in LDCM mission operations.

4.1.3 Training

The LDCM Flight Operations Team (FOT) will be trained and certified to operate the mission. FOT training will include:

- Functionality of the observatory (spacecraft and imaging sensor(s))
- Functionality of MOE software and hardware
- Operations procedures including launch, early orbit, commissioning, nominal, contingency/recovery procedures

Training will take various forms, including exercises to simulate typical day-in-the-life on-orbit Observatory operations and launch rehearsals. To the extent possible/practicable, the FOT will be trained using the system(s) and interfaces that will be used in actual operations. Where this is not possible equipment that emulates the interfaces and simulates performance with high fidelity will be used.

4.1.4 Management Support

Management support will provide all management data needed by the LDCM team. Management support logistics functions will include:

- Property management, to be performed in accordance with NASA and USGS policies.
- Configuration management, to be performed in accordance with the LDCM Configuration Management Plan.
- Risk management, to be performed in accordance with the LDCM Risk Management Plan. It is intended that risk management will be done proactively.
- Safety, to be consistent with NASA and USGS safety policies, plans, and procedures.

4.2 Sustaining Engineering

Sustaining engineering support will be provided throughout the life of the LDCM and will support the Space Segment, Flight Operations Segment, and Data Processing and Archive Segment. All sustaining engineering functions affecting mission operations will be coordinated with the LDCM FOT to assure that routine support does not interfere with operations.

Sustaining engineering efforts for the Space Segment will address:

1. Engineering analysis and expertise to support spacecraft and imaging sensor(s) post-commissioning operations.
2. Investigation of on-orbit anomalies that affect spacecraft or imaging sensor(s) performance and/or anomalies that threaten sensor(s) or spacecraft health and safety.
3. Maintenance and updating of spacecraft and imaging sensor(s) flight software
4. Maintenance of flight software development environment(s).
5. Updating of flight software development environment software licenses and hardware maintenance contracts
6. Maintenance of the Observatory simulator and documentation.
7. Maintenance of imaging sensor(s) EDU components for use in resolving on-orbit anomalies.

Sustaining engineering efforts for the Flight Operations Segment (FOS) will address:

1. Maintenance and updating of MOE software and licenses, hardware, and documentation.
2. Investigation of anomalies of the Mission Operations Element, CAPE, or LGN.
3. Maintenance and updating of CAPE hardware, software and licenses
4. Maintenance and updating of LGN equipment
5. Maintenance of network and IT resources

6. Maintenance of any Communications Security (COMSEC) hardware or software

Sustaining engineering efforts for the Data Processing and Archive Segment (DPAS) will address:

1. Maintenance and updating of the Storage and Archive hardware, software, and licenses
2. Maintenance and updating of the Image Processing hardware, software, and licenses
3. Maintenance and updating of the User Portal hardware, software, and licenses
4. Maintenance of network and IT resources

In general, sustaining engineering activities can be grouped as either software or hardware based. Software sustaining engineering is generally concentrated on monitoring and maintaining operations; however, software modifications may also be required to improve operations. It is expected that the LDCM software will be modular and interoperable so that upgrades are easily and cost-effectively performed. All operational software must follow standard procedures and rigorous testing. Defined software processes will be used and data on how well these processes perform will be collected and used in improvement efforts.

Potential software upgrades and new programs will be evaluated. When the decision is made to use either new or an upgraded version of software, the software will be tested prior to installation. No operational software will be introduced to the LDCM operational system until after it has been thoroughly tested using operational data in a high fidelity simulation environment. Testing and installation of new or modified software will be performed to ensure transparency and non-interference to operations.

The precise way that ground hardware sustaining engineering will be done will be further defined in the FOS and DPAS operations concept documents. It is expected that the FOS and DPAS architectures will be modular in nature so that future upgrades are easily performed. The maintenance of equipment and implementation of new equipment will be conducted with emphasis on transparency to the FOS and DPAS operations. The maintenance and installation process will be compatible with the property management policies referenced in Section 4.1.4.

5 Operational Phases and Scenarios

LDCM operations are described within the context of five phases:

- Pre-Launch
- Launch and Early Orbit
- Commissioning
- Operations
- Decommissioning

5.1 Pre-Launch

The Pre-Launch phase runs throughout the course of imaging sensor(s), spacecraft, and ground-based system development, testing, and integration through the final phase of launch readiness.

In the Pre-launch phase, the LDCM Space Segment spacecraft and imaging sensor(s) will be designed, developed, and qualified. The LDCM Independent Cal/Val Team will participate in imaging sensor(s) testing by performing independent characterization of the radiometric sources used to characterize the imaging sensors. The Independent Cal/Val Team will also review imaging sensor calibration/characterization data.

In parallel with the design and development of the space segment, the design and development of the FOS and DPAS will take place. Imaging sensor test data and test algorithms will serve as inputs to develop the algorithms and software in the Image Processing functions within the DPAS.

Integration and testing (I&T) of each element and segment will be performed during the Pre-launch phase. MOE to observatory I&T will begin with interface/compatibility tests between the MOE and spacecraft communications interfaces and will continue through I&T of spacecraft and imaging sensor(s). MOE interface testing will also be performed with the observatory simulator. Approximately one year before launch, I&T of imaging sensor(s) to spacecraft (observatory I&T) will begin. This will include environmental qualifications of the observatory. RF compatibility testing between the observatory and the LDCM Ground Network, NASA Ground Network, and the SN will be performed. Approximately 8-10 months before launch the MOE will be integrated and tested within the MOC.

Within the FOS and DPAS, element to element I&T will be conducted in the months leading up to segment-level I&T. Approximately 6 - 7 months before launch, segment-level FOS I&T and DPAS I&T will be completed. FOS I&T will include interface testing between the CAPE and MOE/MOC, and between the MOE/MOC and LGN, including I&T of any Communications Security (COMSEC) hardware and software. DPAS I&T will encompass the integration of the DPAS elements and the interface to Users.

A key component of the Pre-launch phase is the training of the LDCM Flight Operations Team (FOT). The FOT will be fully trained and certified to operate the LDCM. Training will include observatory and MOE operations, and day-in-the life exercises using nominal and contingency operations procedures. It is expected that FOT training will be preformed using the actual MOE system(s).

LDCM system integration across all segments will take place and will test the end to end interfaces between the observatory, FOS, and DPAS. This includes end-to-end testing, occurring approximately 3 months prior to launch, to demonstrate that the total LDCM system can plan and execute commands, produce and transmit telemetry, and collect, deliver, and process image data in accordance with requirements. End-to-end testing will utilize the CAPE to generate imaging requests and the MOE to command the

LDCM Observatory to produce a data output that will be captured to the on-board mass storage recorder for playback to ground support equipment. The mass storage data will be flowed through the appropriate ground system elements such as the LGN, MOE, and DPAS, to demonstrate the transfer and ingest of housekeeping and mission data. The DPAS will demonstrate the ability to process data through Level 1 data, and make data available to the user community. At least one end-to-end test will be performed prior to Observatory shipment to the launch site.

Following successful integration and testing of the LDCM, the observatory and associated GSE will be prepared for shipping, and then shipped to the launch site.

The Pre-Launch phase continues with the arrival of the LDCM observatory at its assigned payload processing facility (PPF) at Vandenberg Air Force Base (VAFB). Observatory pre-launch activities required before mating to the launch vehicle are performed at the PPF (e.g. limited performance tests, cleaning, fueling, etc)..

Following final preparations in the PPF, the observatory will be transported to the launch complex where it will be mated to the LV. While mated to the LV, an observatory “aliveness” test will take place to ensure the observatory is functioning as expected. Observatory telemetry will be flowed to the MOE, but there will be no live commanding by the MOE at the PPF or launch complex.

Prior to the LDCM launch, launch dress rehearsals will take place to fully train and prepare launch teams and LDCM FOT. Launch and operations procedures will be followed and refined.

5.2 Launch and Early Orbit

The Launch and Early Orbit phase begins with the final countdown to launch and runs through the early orbit checkout of the LDCM observatory.

The LDCM launch countdown will begin when the NASA/KSC, launch service contractor, LDCM Project, and USAF Western Range (WR) launch teams all agree that there are no impediments to launch. At T=0, the LV begins its ascent from the launch facility. During the final countdown and LV ascent telemetry monitoring and observatory support will be preformed by the launch team at the launch site. During all powered flight portions of the launch and ascent through observatory separation, the LV transmits telemetry to the LV ground tracking stations and/or instrumented aircraft. After achieving the injection orbit, the LV releases the observatory. The LDCM FOT assumes full operations of the LDCM from the MOC after the observatory separates from the LV upper stage. Following observatory release, the LV will perform a collision avoidance maneuver.

Early orbit begins at spacecraft separation from the LV. At this point the launch service contractor will provide the FOS MOE and the NASA Goddard Space Flight Center Flight Dynamics Facility (FDF) with a valid observatory separation state vector to support the first orbit determination. This will be used to update orbit-dependent planning products such as ground station contact data.

The spacecraft will perform a pre-programmed activation sequence after separation from the LV to provide power to the observatory and turn on critical sub-systems. It is anticipated that orbit adjustments will be made during this phase to move the observatory from its initial parking orbit to its nominal orbit. This will include any coordination needed to bring the observatory into the “morning constellation” of Earth observing satellites. These orbit maneuvers may take several weeks and will require periodic orbit determination using observatory telemetry and flight dynamics analysis. The NASA Goddard Space Flight Center Flight Dynamics Facility will be available to support these early orbit activities, if needed.

During early-orbit, the proper functionality of observatory command and data handling functions and attitude and orbit determination and control functions will be demonstrated. The observatory will be capable of transmitting real-time S-band telemetry to the SN for routing to the FOS MOE. Additionally, the observatory may begin transmitting real-time S-band telemetry to the LDCM ground stations and the NASA Ground Network.

During early orbit, activation of the LDCM imaging sensor(s) begins. The imaging sensor(s) will be activated based on a series of steps following out-gassing, including powering on of imaging sensor electronics, functional checkout of any on-board calibration sources, generation of imaging sensor health and status, and collection of the first image.   Imaging sensor data will be transmitted via X-band communications to the LDCM ground stations.

The FOS MOE will receive telemetry through the LDCM ground network and will begin monitoring spacecraft status and health. Imaging sensor data will also be received by the LDCM ground network and routed to the DPAS.

It is anticipated that early orbit activities such spacecraft checkout, orbit raising, imaging sensor(s) out-gassing, activation and decontamination will nominally take place in the first 30 days following launch. Likewise, days 30-60 will nominally include imaging sensor(s) transition to operational mode, first light image collection, and start of on-orbit imaging sensor(s) calibration activities with mission data flow tests

5.3 Commissioning

During on-orbit commissioning and acceptance, the LDCM observatory will demonstrate that it meets pre-defined performance requirements. Commissioning will nominally be performed within 90 days after launch (days 60-90). The Commissioning phase testing will address a series of performance requirements for the spacecraft and imaging sensor(s) such as the first complete 16 day operational test, completion of imaging sensor(s) calibration activities, and development of final test and performance assessments

In this phase, the LDCM FOT will continue to operate the LDCM from the MOC. Additional operational activities include:

- CAPE functions of preparing plans to collect imaging sensor(s) data
- receiving these data via the Landsat Ground Network
- DPAS processing of image data
- Storage of data within DPAS

The commissioning activities will include those imaging sensor data collections and spacecraft activities required to complete observatory on-orbit testing. This will include, but not be limited to, the required calibration activities/maneuvers specified by the Special Calibration Test Requirements (SCTR) document. Commissioning activities for the imaging sensor(s) will be included in the CAPE collection activity requests, and folded into the MOE mission planning and scheduling process. Observatory commissioning activities will be given scheduling priority during the commissioning phase.

In addition, the government's Independent Calibration/Validation Team (ICVT) will submit image collection requests for test data to support their independent test and cal/val operations. This could include, for example, imagery over vicarious calibration sites (WRS-2 scenes used for Landsat radiometric and geometric calibration) or coincident collections with operational high- and moderate-resolution imaging sensors. (These collections will be coordinated with the operators of those systems as needed.) These requests will be provided to the CAPE for collection scheduling so long as they do not conflict with the observatory commissioning schedule. These data will be acquired, processed and archived along with the all other imaging sensor data requests. The ICVT requested data sets will subsequently be extracted from the archive for further processing and analysis by the ICVT.

Once the observatory is fully checked out and calibrated, the on-orbit performance for the acquired image data will be assessed. This includes determining the initial on-orbit calibration parameters (CPF) and presenting the results of on-orbit data processing and analysis. The data sets analyzed will include one or more test scenes processed using government-provided supporting data - ground control points (GCPs) and elevation data (DEM) - after the on-orbit calibration parameters are determined.

At the completion of on-orbit commissioning, an On-orbit Acceptance Review (OAR) will take place. Upon the successful completion of the OAR, NASA, with concurrence from the USGS, will declare the LDCM operational. NASA will then transfer ownership and operation of the LDCM to the USGS.

5.4 Operations

The Operations phase represents the period between observatory commissioning and decommissioning.

The LDCM operations are illustrated by a series of scenarios. These scenarios provide an overview of the major threads through the Operational Concept to describe how major activities are accomplished. The set of scenarios help in understanding how the LDCM system behaves, and serves as a tool to aid in verifying the completeness of the Operations Concept. The scenarios do not portray every possible situation that may be encountered during operations but serve as a basis for further operations planning.

Each scenario includes a brief description, a list of assumptions, a data flow figure, and a table that describes the key functions and data flows. The figure below illustrates the graphical convention used for these scenarios. In this example, a function happens atstep 1 and data flows to step 2. A function occurs at step 2, and then there are two flows shown. In this example, the primary flow is through steps 3, 4 and then 5. This flow always occurs as these steps are numbered sequentially and shown in the same style. There is an optional or alternate flow represented as steps A1, A2 and A3 in the example.

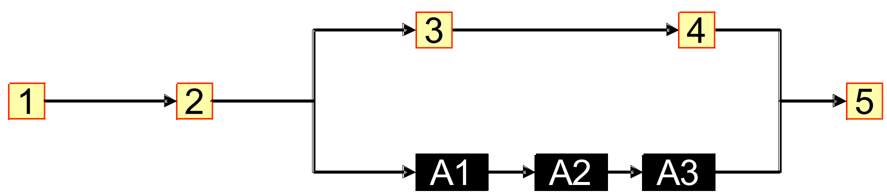

Figure 5-1. Scenario Style Example

5.4.1 Daily Activity Scheduling Mission Scenario (LDCM-01)

5.4.1.1 Description

This scenario illustrates the daily activity scheduling of LDCM image data and providing command loads to the LDCM space segment. This scenario begins with data collection requests and ends with upload of a command sequence to the spacecraft.

5.4.1.2 Assumptions

- All segments are functioning nominally.

5.4.1.3 Walkthrough

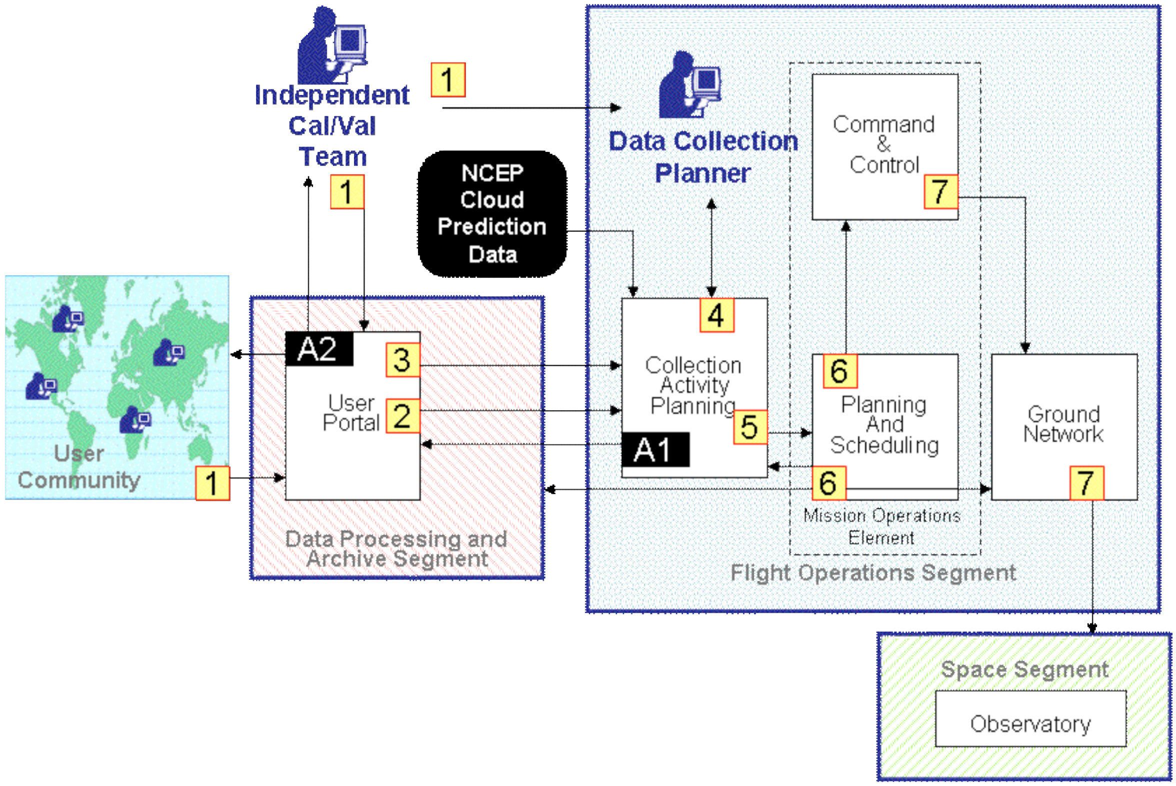

Figure 5-2. Daily Activity Scheduling Mission Scenario (LDCM-01)

Step	Description
1	The User Community generates and submits special image requests that are not in the daily activity or planned data collection schedule. The LDCM Independent Cal/Val Team also generates and submits image requests to support imaging sensor calibration. The User Community interfaces with the DPAS User Portal Element to submit requests, and the Independent Cal/Val Team interfaces with the Data Collection Planner and/or the User Portal to submit calibration requests. Note that all these inputs are optional, as the nominal CAPE activity schedules will largely be automatically generated.
2	The DPAS forwards the image requests to the FOS Collection Activity Planning Element (CAPE) for consideration. This step is also optional, since user image requests will not always be made.
3	The DPAS User Portal Element makes the entire inventory of LDCM metadata in the archive available to the CAPE. This information includes the cloud cover percentages for all scenes in the archive.

Step	Description
4	As part of the CAPE, all special image requests are evaluated by the Data Collection Planner for acceptance or rejection, guided by established policy. The accepted requests and GMAP are combined based on predicted cloud cover probabilities, existing archive quality and extent, and observatory or ground system constraints (provided from the MOE). The accepted requests and GMAP collections are compiled as a scene-based list.
5	The accepted requests and GMAP collections are forwarded to the Planning and Scheduling function of the MOE.
6	The collection activity request is combined with other observatory activities being managed by the MOE Planning and Scheduling functions. Collection requests from the CAPE are converted into timed activities on the observatory (e.g. imaging sensor on/off times, etc.) MOE Planning and Scheduling functions allocate resources, perform any needed activity de-confliction, and generate the observatory activity schedule, which is forwarded to the MOE Command and Control function. The MOE provides the to-be-executed observatory schedule information to the CAPE, the LDCM ground stations, and the DPAS.
7	The MOE Command & Control function prepares and transmits the command load to implement the observatory activity schedule. At the time of the uplink opportunity, the Command & Control function sends the command load through the LDCM Ground Network to the observatory, in real time. The Ground Network sends the command sequence to the LDCM observatory during the scheduled command opportunity.
A1	The status of special requests (if any) is passed back to the DPAS.
A2	The DPAS User Portal Element makes the status information available to the User Community and Independent Cal Val Team member(s) who originally placed the request.

Table 5-1. Daily Activity Scheduling Mission Scenario (LDCM-01)

5.4.2 Collect Imaging Sensor Data (LDCM-02)

5.4.2.1 Description

This scenario illustrates the collection of LDCM image data. This scenario begins with the initial image collection by the observatory and ends with the ingestion into the DPAS archive. This scenario refers only to mission data – imaging sensor and ancillary data. (Note that stored housekeeping telemetry playback is described in scenario LDCM-05.)

5.4.2.2 Assumptions

- All segments are functioning nominally.

5.4.2.3Walkthrough

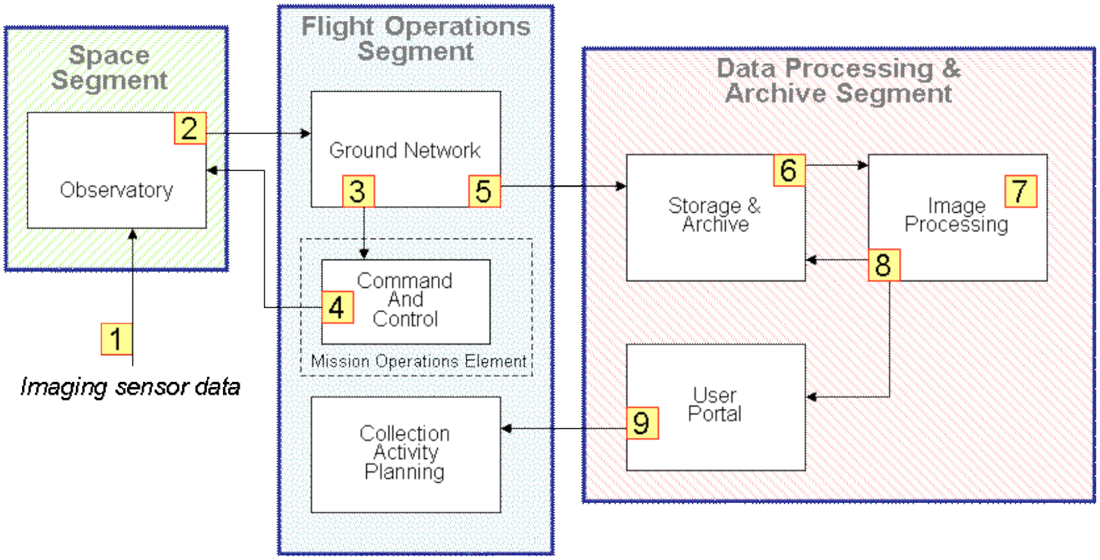

Figure 5-3. Collect Imaging Sensor Data (LDCM-02)

Step	Description
1	The Space Segment observatory imaging sensor(s) collects the scheduled image data (refer to scenario LDCM-01)
2	The observatory stores the data on board until the scheduled downlink opportunity. The X-band imaging sensor data are then downlinked to the LDCM Ground Network.
3	A ground station within the LDCM Ground Network receives the X-band mission data from the Space Segment observatory. In near-real time, the ground station sends receipt acknowledgement messages to the MOE, providing confirmation of the mission data files successfully downlinked.
4	Near the end of the LGN ground station contact, the MOE Command and Control function commands the observatory to unprotect the successfully-received mission data, thus allowing this data to be overwritten in observatory mass storage.
5	The mission data is routed from the LGN ground station to the DPAS.
6	The Storage and Archive Element makes the data available to the Image Processing Element.
7	The Image Processing Element generates scene quality information, metadata and other metrics. The Image Processing Element also extracts trend data to support detailed image assessments.
8	The Image Processing Element makes the archive-formatted data available to the Storage and Archive Element for archival, and makes the metadata for the ingested data available to the User Portal Element.

Step	Description
9	The User Portal Element makes available metadata regarding all data received to the Collection Activity Planning Element.

Table 5-2. Collect Imaging Sensor Data Scenario (LDCM-02)

5.4.3 Flight Software Upload Scenario (LDCM-03)

5.4.3.1 Description

This scenario illustrates the routine update of LDCM flight software. The scenario begins with the generation of new flight software and ends with verification that the in-flight software was successfully updated.

5.4.3.2 Assumptions

- All segments are functioning nominally.
- There is some reason to perform a flight software update, and the nature of the update required is well characterized.

5.4.3.3 Walkthrough

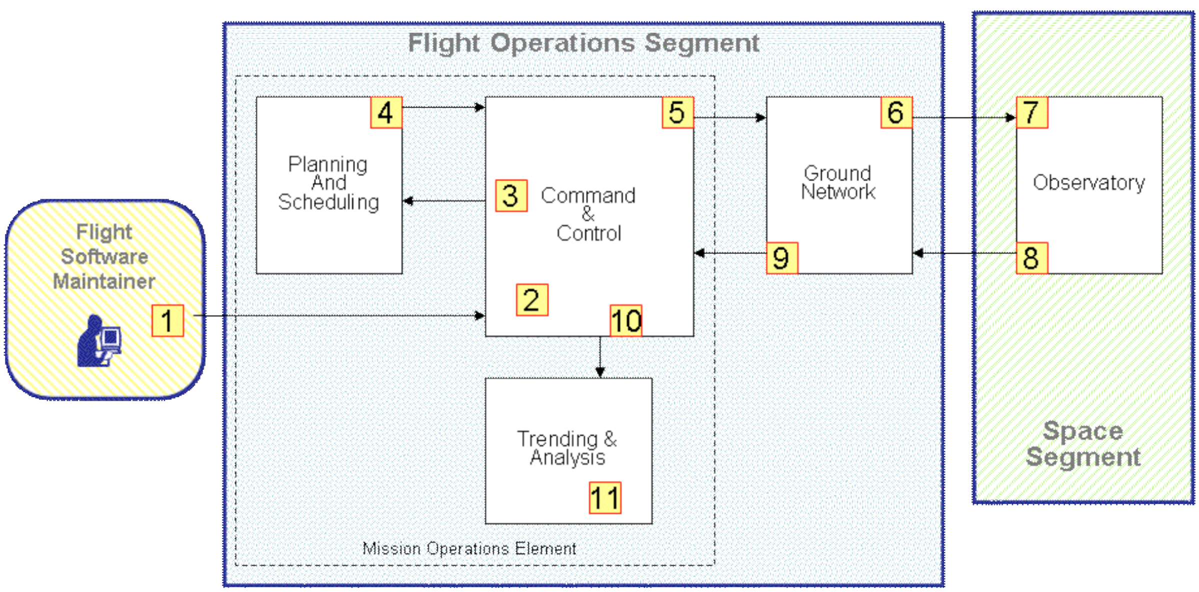

Figure 5-4. Flight Software Update Scenario (LDCM-03)

Step	Description
1	A new flight software update is provided by the imaging sensor(s) or spacecraft flight software developer/maintainer. This is the actual flight software code, which will be installed in the observatory. The update is sent to the MOE Command and Control function.

Step	Description
2	The Command & Control function generates a command sequence, to apply the flight software update to the observatory. The Command & Control function tests the flight software update command sequence using the observatory simulator.
3	A flight software update request is forwarded to the Planning and Scheduling function.
4	Planning & Scheduling incorporates the flight software update into the observatory activity schedule. The observatory schedule is sent back to the Command & Control function.
5,6	The Command & Control function establishes communication with the observatory through the LDCM Ground Network. This communications link is bidirectional and occurs in real time. Through this link, the Command & Control function sends the command load to install the flight software update. Note that it may require multiple contacts with a ground station to uplink an entire flight software update.
7	The observatory receives, verifies, and executes the command load.
8, 9	The command load would typically include instructions to verify the application of the flight software update, such as checksums, reporting the operating version number and so on. The observatory executes these verification commands and the results are sent back to the Command & Control function through the LDCM Ground Network, in real time.
10	The Command & Control function evaluates the verification data to confirm that the command load and flight software execution were successful. The command load is sent to the Trending and Analysis function for archival.
11	The Trending and Analysis function archives the command load and updated flight software.

Table 5-3. Flight Software Update Scenario (LDCM-03)

5.4.4 User Query Order and Product Distribution Scenario (LDCM-04)

5.4.4.1 Description

This scenario illustrates the routine user query, order and product distribution of a particular LDCM scene(s). The scenario begins with a user initiating a search for data and concludes with delivery of data products to the user.

5.4.4.2 Assumptions

- All segments are functioning nominally.

- The user is requesting a product from archived data.

5.4.4.3 Walkthrough

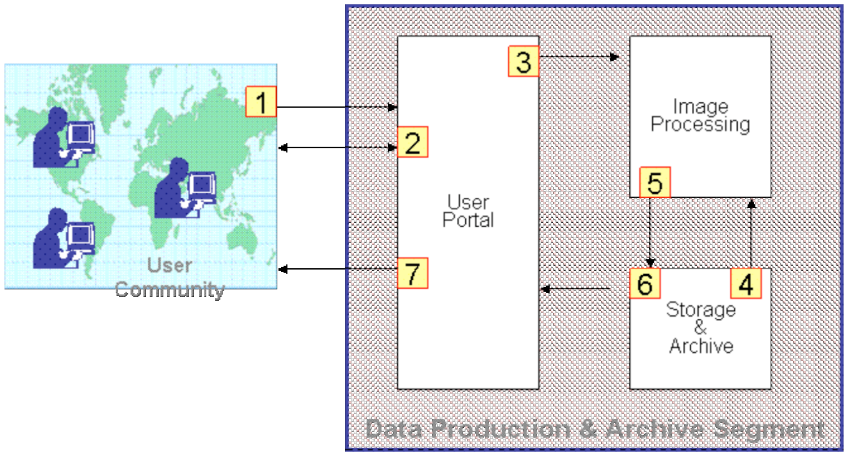

Figure 5-5. User Query Order and Product Distribution Scenario (LDCM-04)

Step	Description
1	A User from the User Community initiates a search for LDCM data.
2	The DPAS User Portal executes the search and presents results to the User. The User may search several more times, and view browse data and metadata about resulting scenes. The User ultimately chooses scenes for ordering. The User Portal obtains additional information from the User if required (through the same interface) and builds the order(s) required to fulfill the User request.
Note; In the case of some large (bulk) data orders, the User functions in steps 1 and 2 may be performed via a machine-to-machine interface.	
3	The User Portal generates the processing requests necessary to satisfy the order and passes them to the Image Processing Element.
4	The Image Processing Element obtains the required data from the Storage and Archive Element.
5	The Image Processing Element generates the required products. These are made available to the Storage and Archive Element.
6	The Storage and Archive Element makes the products available to the User Portal Element.
7	The User Portal Element provides the products back to the User in the format specified. This may be on physical media or via electronic transfer, as specified in the order.

Table 5-4. User Query Order and Product Distribution Scenario (LDCM-04)

5.4.5 Monitor Health & Safety (LDCM-05)

5.4.5.1 Description

This scenario describes the operations performed for both short term and long term monitoring of the spacecraft heath and safety. The scenario begins with the collection of related data on the spacecraft and ends with monitoring / analysis by the FOT operators. (Acting upon any issues found is covered under scenarios LDCM-20 and LDCM-21.)

5.4.5.2 Assumptions

- All segments are functioning nominally.

5.4.5.3 Walkthrough

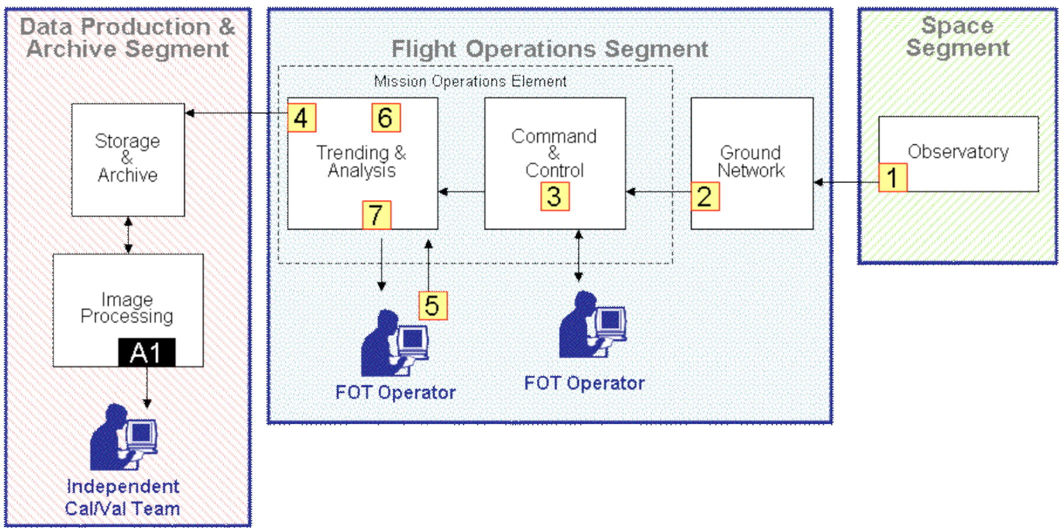

Figure 5-6. Monitor Health & Safety (LDCM-05)

Step	Description
1	The observatory collects telemetry points regarding health & status information of subsystems. These data are stored onboard and later downlinked to the LDCM Ground Network. The real-time telemetry is also downlinked to the Ground Network.
2	A ground station within the LDCM Ground Network receives the telemetry data. The Ground Network routes this data in real time to the FOS MOE.

Step	Description
3	The MOE Command & Control function automatically monitors all key telemetry points for pre-established limit values. Any out-of-limits value is automatically detected. If a FOT operator is not on staff, the MOE will notify FOT staff so appropriate action can be taken. The MOE Command & Control function presents a real-time summary of all key telemetry points and indicators of any out-of-limits telemetry points. A FOT operator interface allows the operator to investigate certain points during the pass.
4	Following each telemetry pass contact, the data are saved within the Trending and Analysis function. The Trending and Analysis function stores all telemetry data collected since launch within the MOE for real to near real-time access by FOT members. The MOE Trending and Analysis function makes a copy of the telemetry data available to the Storage & Archive Element within the DPAS for use by the Independent Cal/Val Team.
The following thread represents the long-term monitoring capability.	
5	A FOT operator (engineer or other FOS team member) interfaces to the MOE Trending and Analysis function, and initiates an analysis session. The operator chooses what data to evaluate, such as battery temperature data or any other data contained in the telemetry archive
6	The MOE Trending and Analysis function retrieves all relevant data from the telemetry archive. Processing is performed as required / specified by the operator conducting the analysis.
7	The MOE Trending and Analysis function presents the results to the operator. The operator may perform a number of steps, including starting new analysis, exporting data for further analysis, updating telemetry point limits and so on.
A1	Independent Cal/Val Team members interface to the Image Processing Element to access observatory state of health data for the long term calibration and performance monitoring of the imaging sensor(s) and any calibration components/devices.

Table 5-5. Monitor Health & Safety (LDCM-05)

5.4.6 Priority Scene Collection & Delivery (LDCM-06)

5.4.6.1 Description

This scenario describes the operations performed when priority data collection requests are received. This scenario begins with the initiation of a request by a User and ends with delivery of data products to the User.

5.4.6.2 Assumptions

- All segments are functioning nominally.
- The priority scene request is approved by the Data Collection Planner as falling within the policy guidelines for such requests.
- The User already has an account on the User Portal, and this account has been pre-cleared to submit Priority data collection requests.

5.4.6.3 Walkthrough

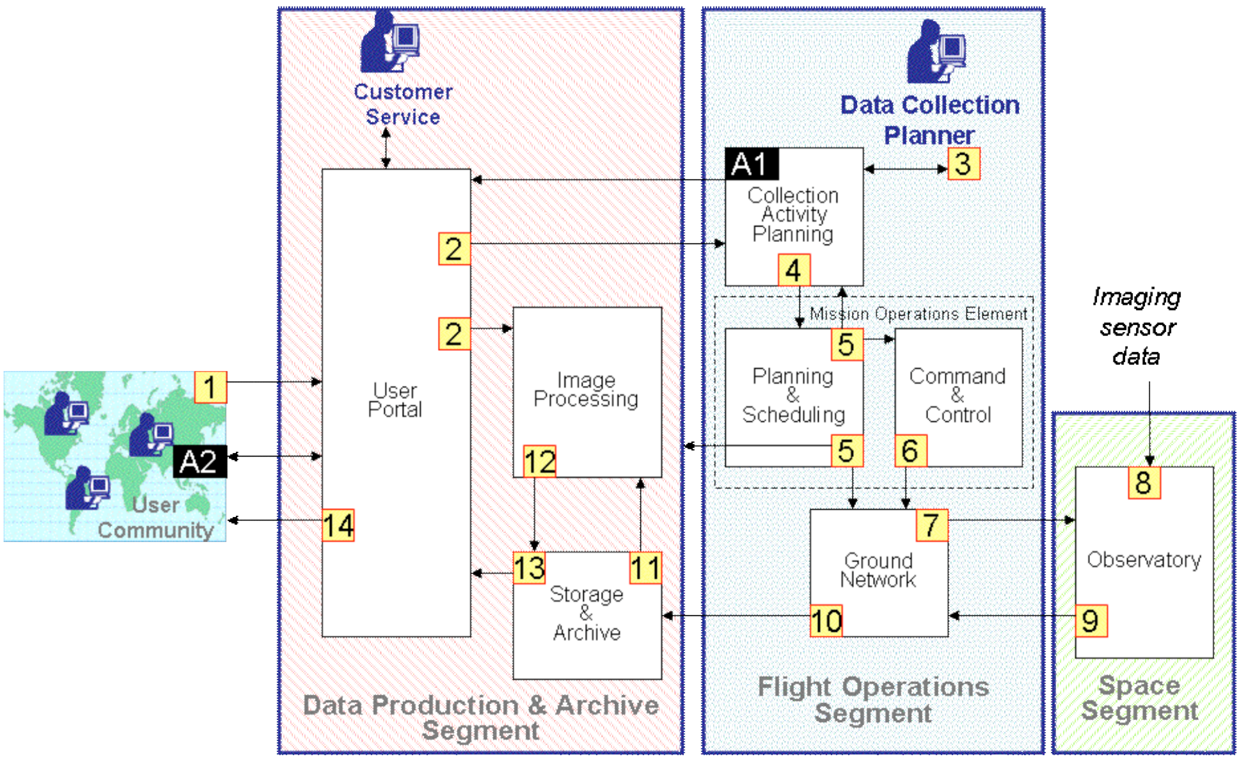

Figure 5-7. Priority Scene Collection & Delivery (LDCM-06)

Step	Description
1	A User from the User Community identifies a need for priority data collection & delivery. The User submits this request to the DPAS through the User Portal Element. (The user may also contact a Customer Service agent on the telephone, who in turn enters the request into the User Portal on their behalf.) There is an account-level control over who may submit Priority data collection requests.
2	The User Portal sends the collecition request to the Collection Activity Planning Element within the FOS. Now, or at any time before step 11, the User Portal Element sends a request to the Image Processing Element for generation of the requested products.
3	The Data Collection Planner interacts with the Collection Activity Planning Element to generate the specific CAPE activity request. The DCP identifies the request as a Priority request.

Step	Description
4	The Collection Activity Planning Element develops a collection activity request, which incorporates the priority request, along with other regularly scheduled collections, adjusted to accommodate the Priority request if necessary. This request is sent to the MOE Planning & Scheduling function.
5	The Planning & Scheduling function develops or revises the observatory activity schedule. The MOE provides the to-be-executed observatory schedule information to the CAPE, the LDCM ground stations, and the DPAS. The observatory activity schedule and resources are passed to the Command & Control function. The Planning & Scheduling function also schedules a Ground Network contact as soon as possible following the observatory collection of the Priority image data. The commands to downlink the priority data may be uplinked in the same contact or a subsequent contact.
6,7	The Command & Control function translates the activity schedule into a command load. At the scheduled time, the Ground Network establishes contact with the observatory. In real time, the Command & Control function sends the command load to the observatory through the Ground Network.
8	The observatory collects the Priority image data.
9	At the next scheduled Ground Network contact, based on observatory commands received from the MOE (step 5), the observatory downlinks all Priority image data.
10	The Priority scenes are sent to the DPAS Storage and Archive Element from the Ground Network station.
11	The Storage and Archive Element makes the priority data available to the Image Processing Element immediately upon receipt.
12	The Image Processing Element generates the requested data products and makes them available to the Storage and Archive Element for temporary storage.
13, 14	The User Portal receives the Priority products from Storage and Archive, and sends the products to the User. In the Priority scenario, it is anticipated that users will normally order electronic delivery.
	This alternate thread illustrates a status capability
A1	The CAPE notifies the User Portal of the particular collections identified to satisfy this request. The Planning & Scheduling function updates this information if there are any changes.
A2	At any time the User may query the User Portal to inquire about the status of the collection request.

Table 5-6. Priority Scene Collection & Delivery (LDCM-06)

5.4.6.4 Scenario Timeline

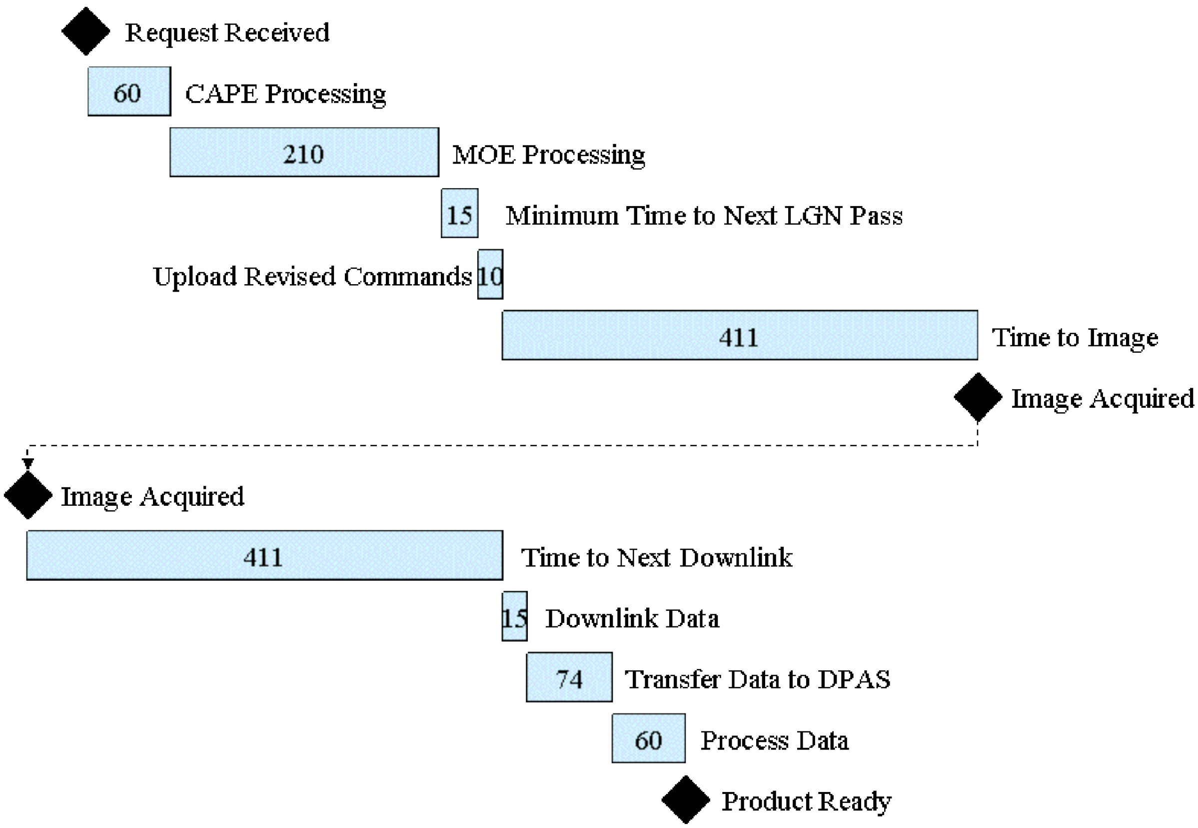

Figure 8. Priority Scene Collection & Delivery Timeline

Figure 8 presents the timeline established to meet the worst case scenarios for scheduling a priority collection, and processing products from a priority collection. The numbers in each block represent the minutes allocated to that step to meet the timeline. The table below ties the steps on the timeline to the scenario steps from section 5.4.6.3 and provides additional notes.

The LGN ground station locations of Sioux Falls, SD, and Fairbanks, AK, create a period of several orbits where the observatory is not in contact with the LGN. The worst case from a scheduling point of view is to schedule a priority scene which would be collected at the very end of this contact gap. For the time from collection to production, the worst case is a scene collected at the very beginning of this contact gap. Although in practice back-to-back contact gaps of 411 minutes will not occur, these timelines are presented this way in order to show the worst cases for both planning & scheduling and image production purposes.

Timeline Step	Scenario Steps	Notes
Request Received	1	

Timeline Step	Scenario Steps	Notes
CAPE Processing	2,3,4	
MOE Processing	5,6	
Minimum Time to Next LGN Pass	6	The MOE cannot schedule a ground station contact in less time than this
Upload Revised Commands	7	
Time to Image	8	This represents the time from the last Alaska LGN contact to the last possible daytime land image until the first LGN contact at the end of the daily contact gap.
Image Collected	8	
Time to Next Downlink	9	This represents the time assuming a scene was collected just after the last Alaska LGN contact, until the first LGN contact after the daily contact gap.
Downlink Data	9	
Transfer Data to DPAS	10	The worst case is to assume data was downlinked to a station other than Sioux Falls, SD, so network transfer must take place.
Process Data	11,12,13	
Product Ready	14	

Table 5-7. Priority Scene Collection & Delivery Timeline Details

5.4.7 Maintain Orbit (LDCM-07)

5.4.7.1 Description

This scenario describes the processes related to station keeping for the LDCM spacecraft. The scenario begins with measurements of the spacecraft position and ends with confirmation that maneuvers were completed successfully.

5.4.7.2 Assumptions

- All segments are functioning nominally.

5.4.7.3Walkthrough

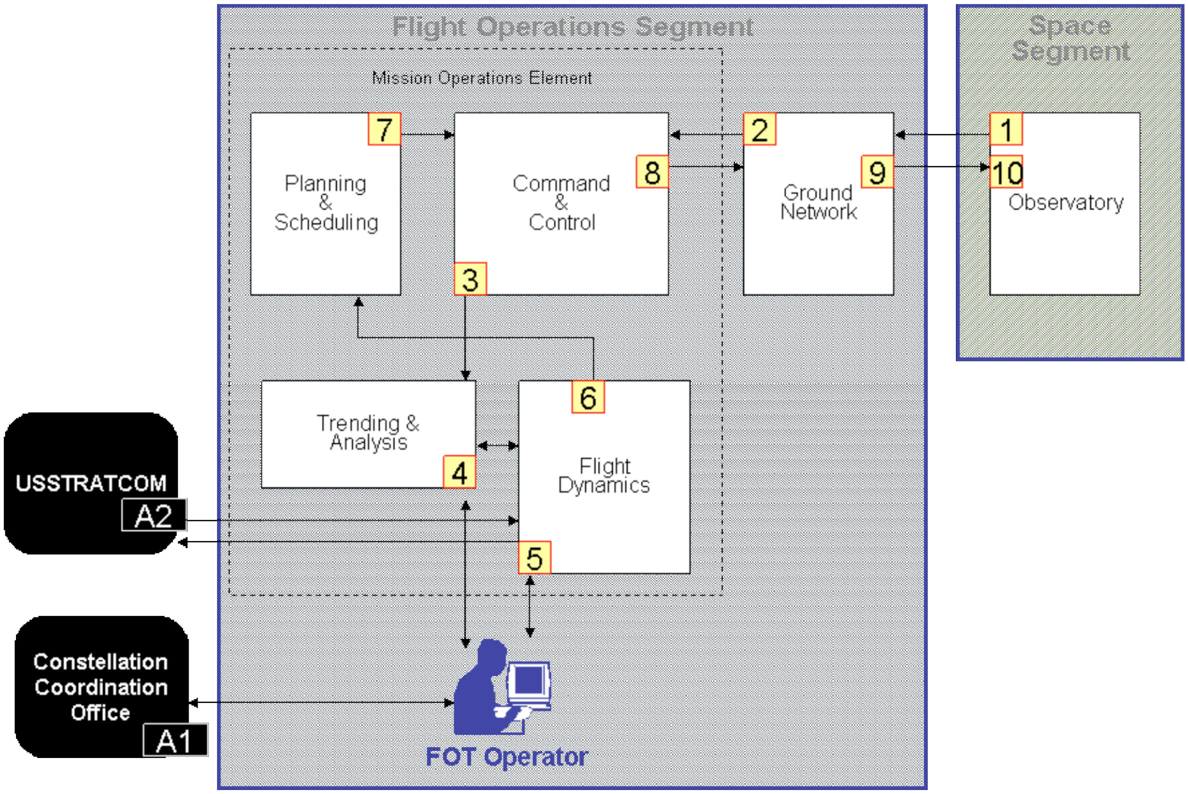

Figure 5-9. Maintain Orbit (LDCM-07)

Step	Description
	This scenario begins with measurements relevant to the determination of the spacecraft precision ephemeris. These measurements occur asynchronously and are represented as parallel flows for the purpose of this scenario.
1	The observatory performs measurements relevant to orbit determination. These measurements are included as part of the standard telemetry streams during contacts with stations in the Ground Network.
2	The Ground Network stations forward the telemetry data to the Command & Control function.
3	The Command & Control function passes all the telemetry data to the Trending and Analysis function for archival after the ground network contact is completed. These data include the observatory measurements.
A1	The GSFC Constellation Coordination Office coordinates with the FOT Operators. This coordination is to ensure adequate operational safety in the group of satellites flying in the same orbital plane as LDCM.

Step	Description
A2	The USSTRATCOM sends orbital debris monitoring alerts to the Flight Dynamics function. These messages consist of ellipsoid volume data representing buffer regions between LDCM and other orbiting debris that could collide with LDCM. Two volumes are used - the “monitor volume” (larger) and the “tasking alert volume” (smaller). Predicted monitor volume violations are reported in routine messages from USSTRATCOM. Violation of the tasking alert volume initiates additional tracking of the offending objects by USSTRATCOM to refine the orbit for more accurate conjunction assessment, which is forwarded to the FOT.
4	An FOT operator(s) evaluates telemetry and makes a determination as to whether a maneuver is required to maintain orbit and mission safety. Additional operations management approval for certain types of maneuvers may be required.
5	The FOT Operator uses the Flight Dynamics function to derive the details of the orbital maneuver(s) required. Predicted ephemerides corresponding to planned maneuvers are also sent to USSTRATCOM for predicted conjunction assessment(s). The potential for conjunctions are assessed prior to final maneuver planning and selection.
6	A maneuver request is sent to the Planning and Scheduling function.
	Note that the planning of maneuvers is done well in advance of the maneuver. Steps 4, 5, 6 and 7 are all expected to occur after a significant amount of coordination on the part of FOT staff. Steps 4, 5, 6 and 7 may be completed days or even weeks in advance of the actual maneuver.
7	The Planning and Scheduling function allocates resources for executing the maneuver. This includes scheduling the Ground Network contact for the commanding, and potentially identifying a period of time during which no mission data collections will be performed, for input to the scheduling process. The maneuver is then incorporated into the observatory activity schedule.
8, 9	The Command and Control function transmits the command load to implement the observatory activity schedule, including the maneuver. At the time of the contact, the Command & Control function establishes contact with the observatory through the Ground Network. This communication is accomplished in real time. The command load is sent to the observatory through the Ground Network.
10	The observatory executes the commanded maneuver sequence.
	Note that this is an iterative process. Following the maneuver, measurements are taken to ensure that the observatory is in the intended orbit. Therefore the system proceeds to steps 1 and 2 of this scenario, and repeats.

Table 5-8. Maintain Orbit (LDCM-07)

5.4.8 IC Scheduling and Delivery (LDCM-08)

5.4.8.1 Description

This scenario illustrates the primary interactions between LDCM and the International Cooperators (ICs). This scenario begins with the IC request for image collection and ends with the delivery of data to the IC.

There are two ways for an IC to request data. A mask providing relative scene priorities can be submitted as seasonal or operational considerations change. Specific individual scenes can be requested using the functionality provided by the DPAS User Portal.

5.4.8.2 Assumptions

- All segments are functioning nominally.

5.4.8.3 Walkthrough

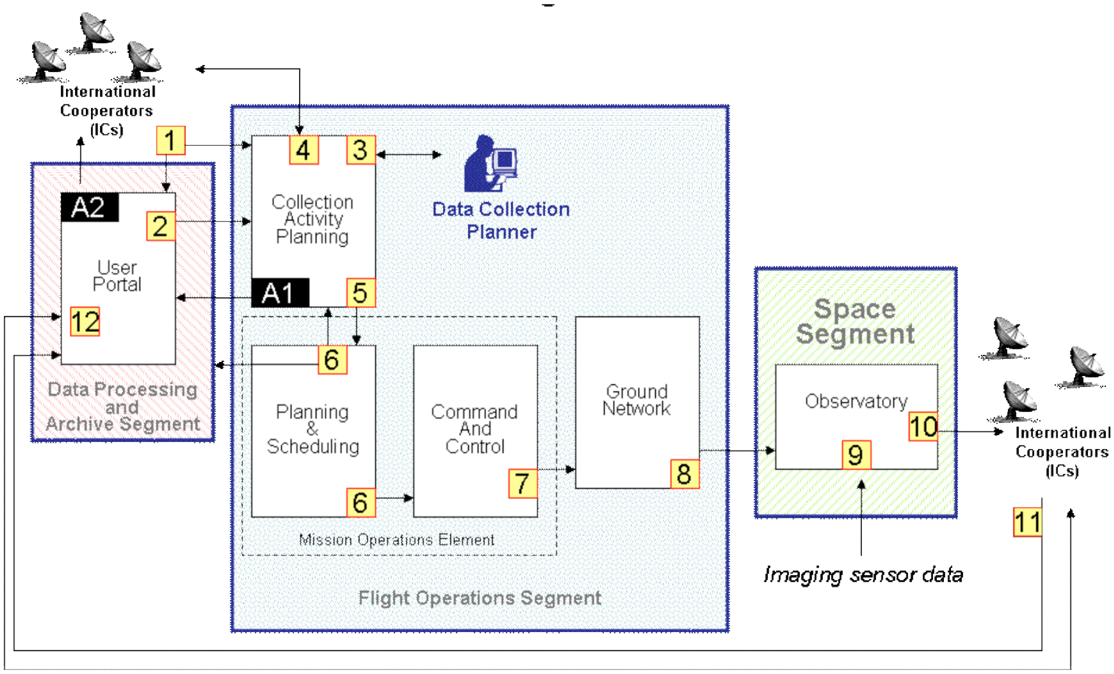

Figure 5-10. IC Scheduling and Delivery (LDCM-08)

Step	Description
1	An IC generates and submits an image collection request that is not in the daily activity or collection schedule. The IC interfaces with the DPAS User Portal to submit individual scene requests. The IC interfaces with the Collection Activity Planning function to submit an IC-mask of relative scene priorities.
2	The DPAS forwards the collection request to the FOS for consideration.

Step	Description
3	As part of the Collection Activity Planning Element, all IC requests are evaluated by the Data Collection Planner (DCP) for acceptance or rejection, guided by established policy. The accepted requests and GMAP are combined based on predicted cloud cover probabilities, existing archive quality and extent, and engineering constraints (provided by the MOE) to form the collection activity request.
4	The Collection Activity Planning Element coordinates with the IC for the availability and scheduling of IC ground stations resources to receive LDCM data. Each IC is coordinated with and scheduled on an individual basis.
5	The collection activity request is forwarded to the MOE.
6	The collection activity request is combined with other observatory activities being managed by the MOE Planning and Scheduling functions. MOE Planning and Scheduling functions allocate resources, perform any needed activity de-confliction, and generate the observatory activity schedule, which is forwarded to the MOE Command and Control function. The MOE provides the to-be-executed observatory schedule information to the CAPE, the LDCM ground stations, and the DPAS.
7	The Command and Control function uses the activity schedule to generate a command sequence, and forwards this to the LDCM Ground Network.
8	The Ground Network sends the command sequence to the LDCM observatory during the scheduled command opportunity.
9, 10	The observatory collects the scheduled image data. In real-time, the observatory transmits the image data to the IC ground station. The image data are also stored on board the observatory for future downlink to an LDCM ground station.
11	The IC ground station notifies the DPAS User Portal Element of the receipt of the X-band data and provides related information associated with the collection.
12	If additional calibration data is needed, the ICs access it through the DPAS User Portal.
A1	The status of IC requests (if any) is passed back to the DPAS.
A2	The DPAS User Portal Element makes the status information available to the International Cooperators who originally placed the request.

Table 5-9. IC Scheduling and Delivery (LDCM-08)

5.4.9 Communications with the SN (LDCM-09)

5.4.9.1 Description

This scenario describes the interactions between LDCM and the SN. This scenario begins with the scheduling of the SN resources and ends with the receipt of S-band telemetry stream.

5.4.9.2 Assumptions

- The mission is in early orbit, contingency operations, or proficiency testing phase
- All segments are functioning nominally.

5.4.9.3 Walkthrough

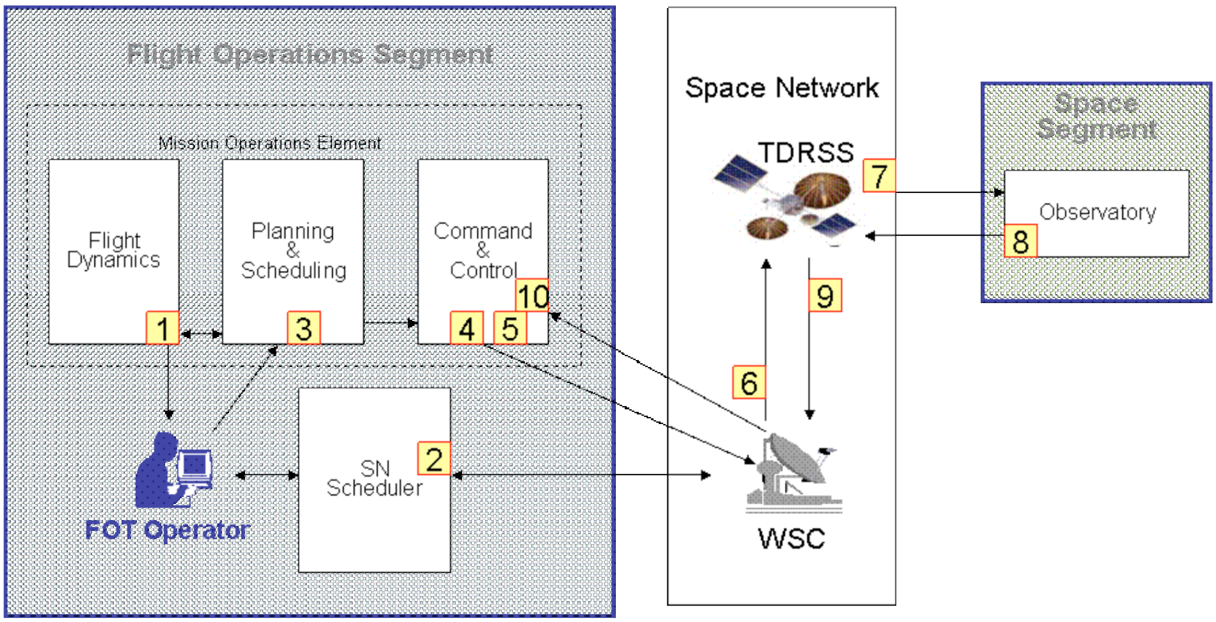

Figure 5-11. Communications with the SN (LDCM-09)

Step	Description
1	FOS MOE Flight Dynamics and Planning and Scheduling functions define/plan the desired SN contact times. An FOT operator uses this information to schedule SN resources.
2	The SN custom scheduling tool in the MOC is used by an FOT operator to schedule SN resources through the SN White Sands Complex (WSC). This process may start 21 days in advance and is iterated with updated flight dynamics information as the planned SN contact draws nearer.
3	The SN contact activity is incorporated into the observatory activity schedule within the MOE Planning and Scheduling function. The activity schedule is forwarded to the MOE Command and Control function.
4	Prior to the scheduled contact time, the MOE Command and Control function generates a link service request and forwards this to the WSC.
5	The MOE Command and Control function generates a command sequence using the observatory activity schedule, and forwards this to the WSC.

Step	Description
6, 7	The WSC ground station transmits the S-band communications stream to an SN satellite (TDRSS). The SN satellite contacts the LDCM observatory and relays to it the S-band communication.
8, 9	The observatory generates telemetry data and transmits an S-band communications stream to the SN satellite. The SN satellite relays the S-band communications stream to the SN WSC ground station.
10	The WSC ground station forwards the received S-band telemetry data to the MOE Command and Control function.
At this point this scenario is over. In practice, several scenarios could be initiated at this point, including LDCM-03, LDCM-05, LDCM-07, and LDCM-20.	

Table 5-10. Communications with the SN (LDCM-09)

5.4.10 Safehold/Autonomous Failsafe Occurrence and Recovery Mission Scenario (LDCM-20)

5.4.10.1 Description

This scenario illustrates the non-nominal activity associated with an anomaly identified onboard the observatory and the fail-safe process the observatory will complete without ground interaction. The scenario begins with a fault condition and ends with notification of the FOS that the observatory is in safe-hold mode.

5.4.10.2 Assumptions

- The FOS and DPAS are functioning nominally.
- The observatory flight software has been developed such that continuous health and status data is recorded, analyzed and logged on board, allowing for detection of fault situations.
- A fault situation (not intermittent) occurs on board the observatory, which triggers a safehold mode.
- The observatory successfully enters safehold mode and cannot change modes without ground commanding.

5.4.10.3 Walkthrough

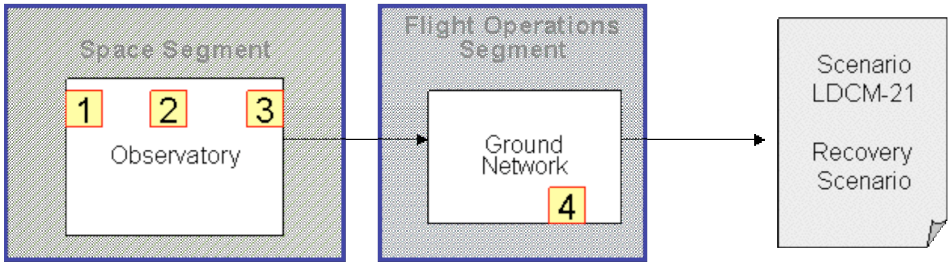

Figure 5-12. Safehold/Autonomous Failsafe Occurrence and Recovery Mission (LDCM-20)

Step	Description
1	A fault condition occurs on board the observatory. The observatory detects the condition during routine internal health and status monitoring. The observatory verifies the condition and continues data logging.
2	The observatory initiates the safe-hold protocol by shutting down all non-essential hardware and processes (but continuing to log data) and continues until successfully completed. After completion of safing, data logging continues.
3	The observatory downlinks S-band data to a ground station within the FOS Ground Network at the next opportunity.
4	The Ground Network routes the data to appropriate FOS teams for analysis and archiving. The routing of telemetry data is identical to that shown in scenario LDCM-05.
At this point this scenario is over. In practice, the system immediately initiates scenario LDCM-21 upon detection of the safe-hold condition within the FOS.	

Table 5-11. Safehold/Autonomous Failsafe Occurrence and Recovery Mission Scenario (LDCM-20)

5.4.11 Non-Autonomous Anomaly Correction (LDCM-21)

5.4.11.1 Description

This scenario describes the process of anomaly resolution. The scenario begins with the establishment of an Anomaly Resolution Team and ends with the determination of the appropriate procedures to correct the anomaly.

5.4.11.2 Assumptions

- An anomaly has occurred and has been detected by the FOT

5.4.11.3 Walkthrough

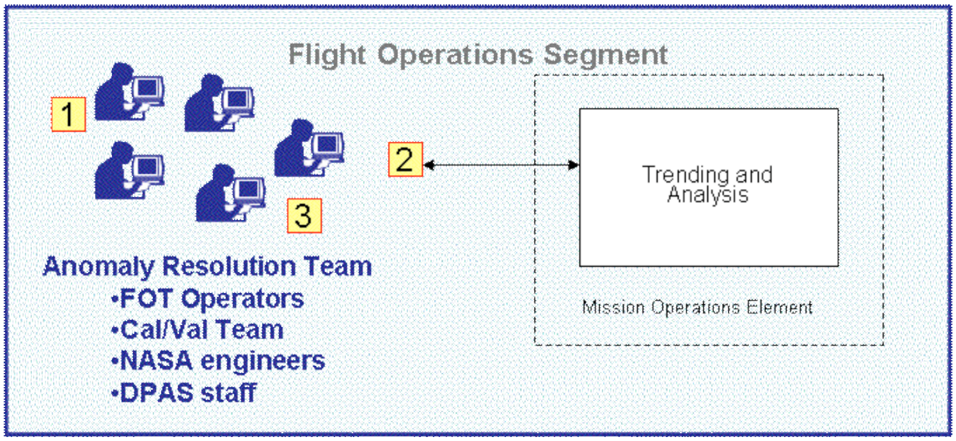

Figure 5-13. Non-Autonomous Anomaly Correction (LDCM-21)

Step	Description
1	An Anomaly Resolution Team (ART) is formed. The ART may be comprised of the following representatives, depending on the type of anomaly: FOT operators, spacecraft and imaging sensor(s) sustaining engineering support, NASA discipline engineering support, DPAS support, and the Independent Cal/Val team.
2	The ART interfaces to the Trending and Analysis functions to study and analyzes observatory engineering and state of health data.
3	The ART develops and evaluates possible anomaly resolution options using MOE tools/capabilities, engineering and design data, and other operations support tools and information. A spacecraft anomaly report is generated and becomes the official document to track and close the incident Steps 2 and 3 may be performed iteratively until the anomaly resolution plan and procedures are determined.
At this point, this scenario ends. Depending on the type of anomaly and resolution, a number of different events or scenarios could be initiated at this point including a flight software update (LDCM-03), activation of redundant flight systems, a modification in image data collection or processing, or others.	

Table 5-12. Non-Autonomous Anomaly Correction (LDCM-21)

5.4.12 Retransmission (LDCM-22)

5.4.12.1 Description

This scenario describes two possible levels of LDCM data retransmission which the LDCM system will provide.

5.4.12.2 Assumptions

- Scenario Flow A: LDCM imaging sensor data was collected and downlinked successfully. Following successful ground receipt as confirmed by LGN, the MOE commanded data to be unprotected in the observatory mass storage. The LGN transferred the imaging sensor data to the DPAS, and the resulting data was judged invalid.
- Scenario Flow B: LDCM imaging sensor data was collected by the observatory and downlinked to the LGN. A portion of the data downlinked could not be confirmed as successfully received during the LGN contact. The portion that could not be confirmed remains on board the observatory in mass storage.

5.4.12.3 Walkthrough

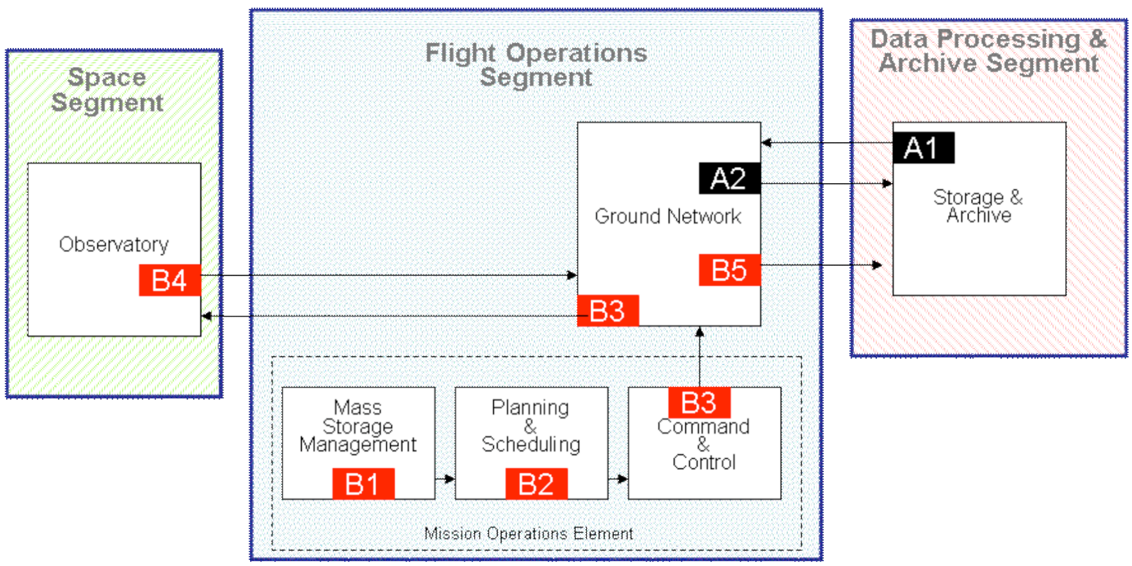

Figure 5-14. Retransmission (LDCM-22)

Step	Description
A1	The Storage & Archive Element requests that the Ground Network re-transfer LDCM data to the Storage & Archive Element. This request can only be placed within the fixed period of time for which the Ground Network nodes cache data for this purpose.
A2	The Ground Network makes the LDCM data available to the Storage & Archive Element.

Step	Description
B1	Based on observatory telemetry and LGN ground station contact data, the MOE mass storage management function identifies the data in observatory mass storage that must be re-downlinked. Mass storage utilization is also re-analyzed to account for the data still in mass storage and upcoming imaging sensor data collections. Note: The DPAS, through CAPE, could also originate a request for re-downlink for data that has been found to be of poor quality by the DPAS, provided that the data was flagged for protection and has not yet been overwritten within observatory mass storage. The MOE mass storage management functions will be capable of managing this by maintaining the protection even after downlink receipt acknowledgement.
B2	The MOE Planning and Scheduling function schedules the data for re-downlink in an upcoming pass. Re-planning and re-scheduling of imaging sensor data collections may be needed to account for the unavailable space in observatory mass storage.
B3	The Command and Control function transmits a command for re-downlink from the observatory. This could be done either during the normal commanding schedule, or as an additional commanding event, as the situation warrants.
B4	The Observatory sends the requested data back down to the Ground Network as requested in the command load.
B5	The Ground Network makes the LDCM data available to the Storage & Archive Element.

Table 5-13. Retransmission (LDCM-22)

5.4.13 Backup Flight Operations

As discussed in section 3.2, the LDCM has a backup flight operations center capability. The Mission Operations Manager can transfer operations responsibility to the backup location at any time. The switchover may be initiated from the backup mission operations center, in the event the primary location is unexpectedly non-operational. No scenario is shown for this because the details of activating the backup mission operations center are design-specific. All nominal and non-nominal operations can be executed from the backup location.

To ensure that the backup capability is ready, operations will be tested from the backup location on a routine periodic basis.

5.5 Decommissioning

At the end of the mission, the LDCM will undergo decommissioning. The decommissioning of the LDCM observatory will comply with the NASA Safety Standard Guidelines and Assessment Procedures for Limiting Orbital Debris (NSS 1740.14) and the NASA Policy for Limiting Orbital Debris Generation (NPD 8710.3).

6.0 Design Reference Case

A Design Reference Case has been developed to present a 15 orbit scenario for the LDCM mission. This reference case is intended to incorporate all the driving operational cases into a single day's operation to show a worst case operational scenario. The DRC is presented in tabular form in Appendix B. The table includes one row for every WRS-2 path/row orbit increment where either imaging sensor data is collected or X-band data is downlinked.

This design reference case (DRC) assumes that all imaging sensor data is protected on-board from overwriting until it is downlinked to an LGN ground station. Within the same ground station contact, the data downlinked will be unprotected and available for overwriting in observatory mass storage.

The DRC color coding is as follows:
green = imaging sensor data collected
yellow = downlink to LGN station
red = off-nadir collection

The DRC column headings are explained in the following table.

Column Heading	Explanation/Description
Acquired?	Indicates a 1 for any time the imaging sensor(s) is collecting data for downlink
Off-nadir?	Indicates a 1 for any time the collected imaging sensor data is an off-nadir image of the Earth
Downlinked	Indicates the number of simultaneous X-band downlink streams to an LDCM Ground Network ground station. LGN ground stations can receive up to 2 simultaneous streams of either 1 real-time + 1 playback or 2 playbacks, as indicated in the Comment column.
broadcast	Indicates the number of simultaneous real-time X-band downlink streams to International Cooperator (IC) ground stations
station_id	Includes the LGN ground station

	identifier for the station receiving the downlink. LGS = Landsat Ground Station, Sioux Falls, South Dakota AK = Alaska Ground station, Fairbanks, Alaska
Ic1, ic2, and ic3	Includes the IC ground station identifiers for the IC stations receiving real-time X-band downlinks
Comment	Includes additional information about the activity, including calibration events, types of downlinks, etc.

Appendix A: Potential List of International Cooperator Ground Stations

Station	Location	Latitude (deg)	Longitude (deg)	Altitude (km)
ASN	Alice Springs, Australia	23:45:32.0000 S	133:52:56.0000 E	0.579
BJC	Beijing, Peoples Republic of China	40:27:02.0000 N	116:51:26.0000 E	0.109
BKT	Bangkok, Thailand	13:43:48.0000 N	100:47:24.0000 E	0.002
COA	Cordoba, Argentina	31:31:27.0000 S	64:27:49.0000 W	0.73
CUB	Cuiaba, Brazil	15:33:10.0000 S	56:04:24.0000 W	0.268
DKI	Parepare, Indonesia	03:58:41.0000 S	119:38:59.0000 E	0.09
GNC	Gatineau, Canada	45:34:52.6800 N	75:48:22.3200 W	0.286
HAJ	Hatoyama, Japan	36:00:13.0000 N	139:20:53.0000 E	0.088545
HIJ	Hiroshima, Japan	34:21:52.7800 N	132:22:43.0170 E	0.01915
HOA	Hobart, Australia	42:55:32.0000 S	147:25:14.0000 E	0.15
JSA	Johannesburg, South Africa	25:53:24.0000 S	27:42:00.0000 E	1.543
KIS	Kiruna, Sweden	67:52:36.0000 N	21:03:44.0000 E	0.51
MPS	Maspolomas, Spain	27:45:36.0000 N	15:37:48.000 W	0.154
MTI	Matera, Italy	40:39:00.0000 N	16:42:00.0000 E	0.53
PAC	Prince Albert, Canada	53:12:45.0000 N	105:56:01.0000 W	0.489
PF1	Poker Flat (DataLynx), Alaska	65:07:04.5303 N	147:26:00.5960 W	0.519074
SEK	Seoul, Korea	37:27:33.3714 N	127:04:07.2243 E	0.14947
SGS	Svalbard, Norway	78:13:50.6006 N	15:23:22.9048 E	0.480434
TFT	Taipei Fixed Taiwan	25:05:34.9000 N	121:23:24.0000 E	0.27
UPR	University of Puerto Rico	18:12:39.9600 N	67:08:12.4800 W	0.1

Appendix B: Design Reference Case

See Excel file attachment.